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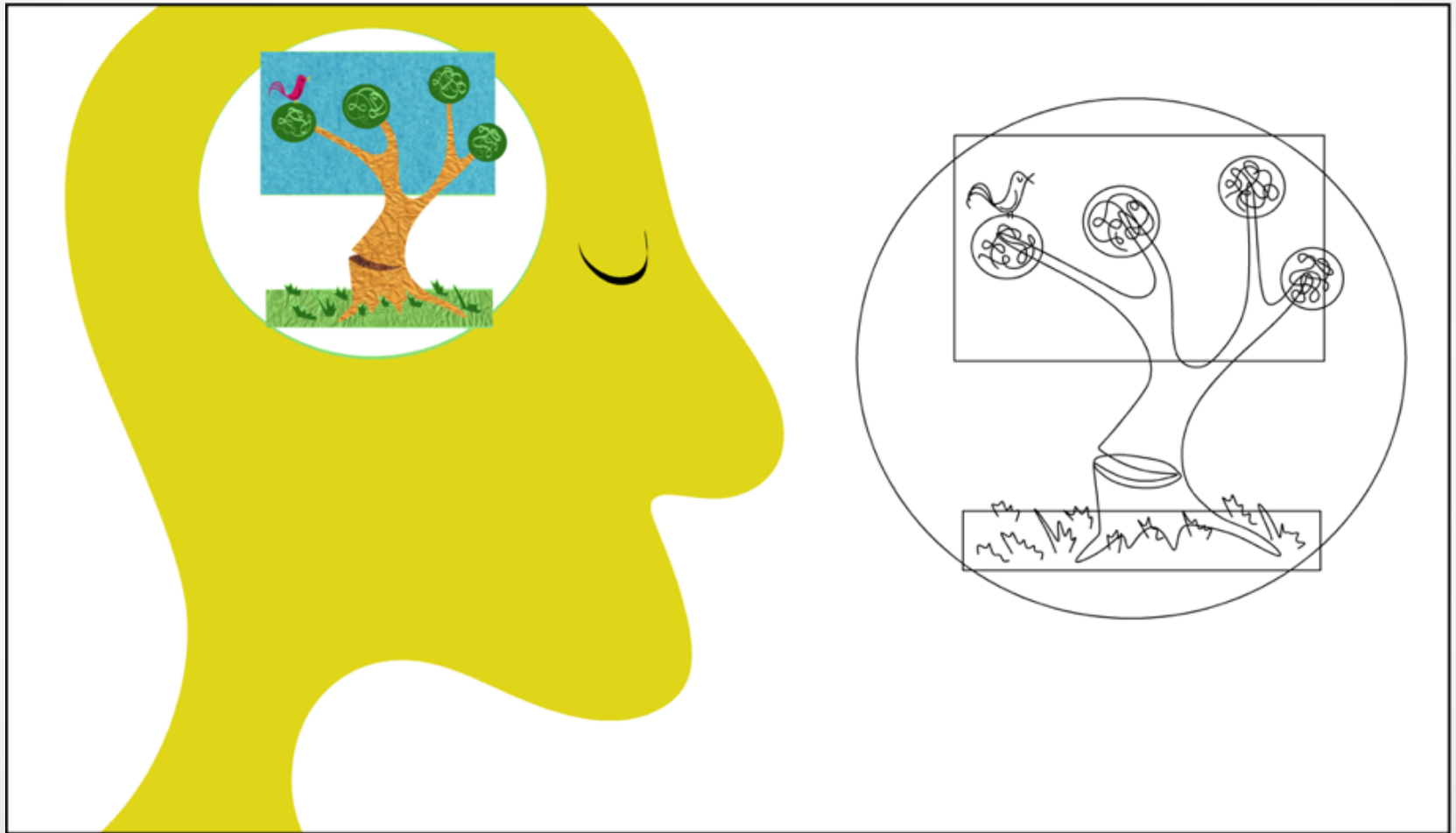
Course Title:

Basic Cognitive Processes

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Lecture 14: Basics of Psychophysics

Psycho – physics: Measuring Sensation



What is Psychophysics?

- Two words: Psychology + Physics
- Psychophysics involves the determination of the psychological reaction to events that lie along a physical dimension. e.g. loudness, lightness, brightness etc.
- G. Boring (1950) claims that the introduction of techniques to measure the relation between internal impressions (the psycho) & the external world (the physics) marked the onset of scientific psychology.

Basic Concepts

- the problem of psychophysics is a seeming paradox:
 - it requires objectification of a subjective experience.
- subjective experience is called **sensation**.

- Now, two issues:
 - measuring sensations is very difficult, because they are not open to public measurement, as light intensity or weight of a stone.
 - the internal judgments are not identical to the amount of physical energy influencing the sensory apparatus.

- Examples:
 - The amplifier or radio - dial that you use to increase the volume (i.e. perceived loudness) of music from your TV, does not bear a one-to-one relation between movements of the dial & increases in physical energy.
 - rather, the dial has to be calibrated so that its movements increase intensity proportional to increments in loudness.
 - thus, doubling the volume level on the dial has to increase physical energy about 10 times to produce a twofold increase in loudness.

- Also, the psychophysical relations between stimulus & judgment depend on the particular sensory modality that is stimulated.
- pain judgments in response to increases in electrical intensity of shocks applied to the skin grow much more rapidly than do loudness judgments in response to increase in sound energy.
- for one shock to be judged twice as painful as another, the intensity of the shock needs to have been increased about one-third.

- Psychophysics tries to solve this problem by closely linking perceptual experience to physical stimuli.
- the basic principle is to use the physical stimuli as a reference system.
- stimulus characteristics are carefully & systematically manipulated & observers are asked to report their perception of the stimuli.
- The art of psychophysics is to formulate a question that is precise & simple enough to obtain a convincing answer.

- “Can you hear the tone?”
 - yes! *detection*
- “Can you tell which tone?”
 - yes! *identification*

- Problems arise in case of weak signals or noise in the environment.
- In such cases, the task is one of *discrimination* of the stimulus, or signal, from a noisy background, and the task is performed under uncertainty.

- So, What determines when we can:
- detect a signal.! or
- discriminate a signal from noise!

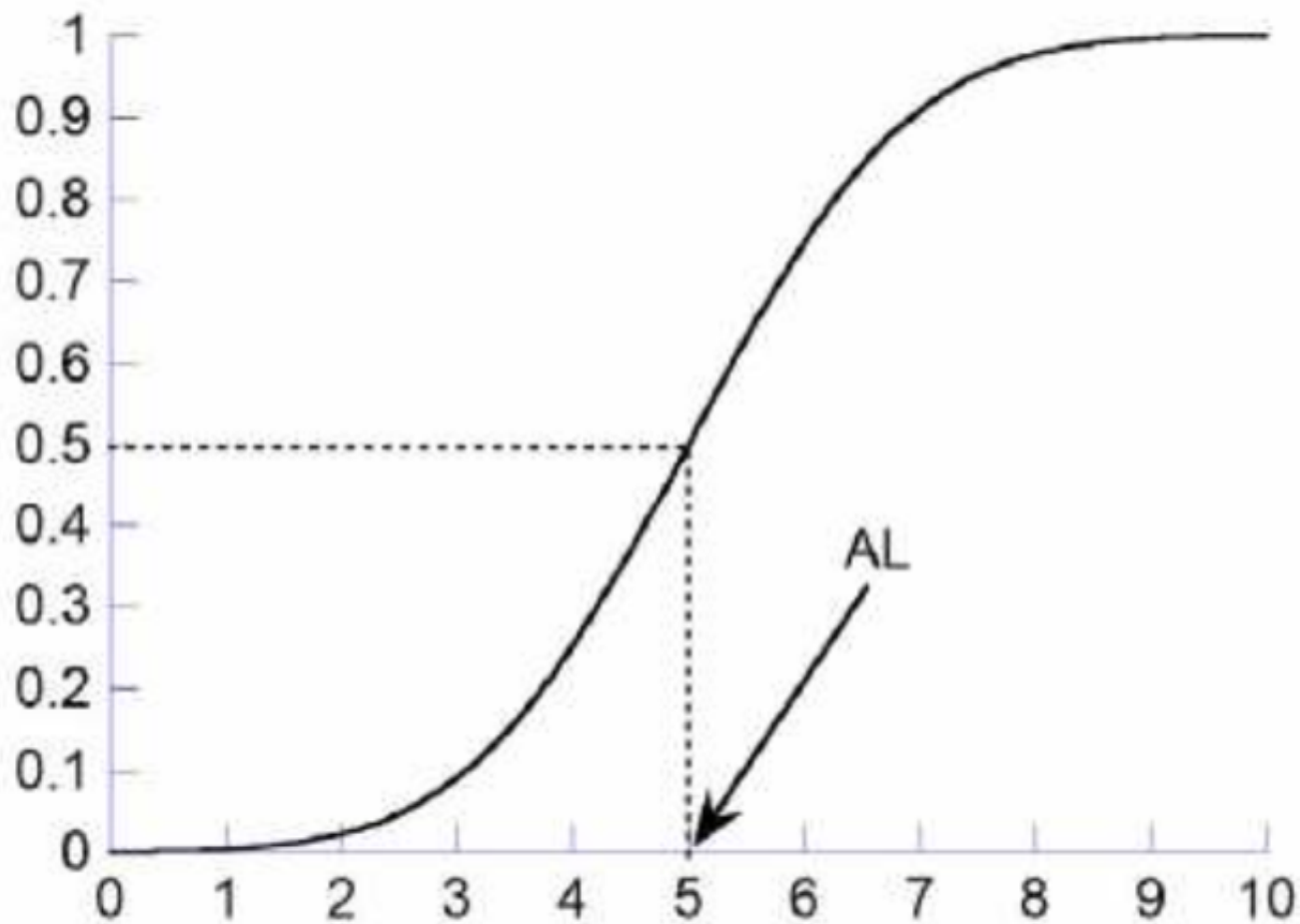
Sensory Threshold



- the most basic function of any sensory system is to detect energy or changes of energy in the environment.
- this energy can consist of chemical (as in taste or smell), electromagnetic (vision), mechanical (audition, proprioception & touch) or thermal stimulation.

- in order to be noticed, the stimulus has to contain a certain level of energy. this minimal amount of energy is called *absolute threshold*.
- according to Fechner, "*lifts its sensations over the threshold of consciousness.*"

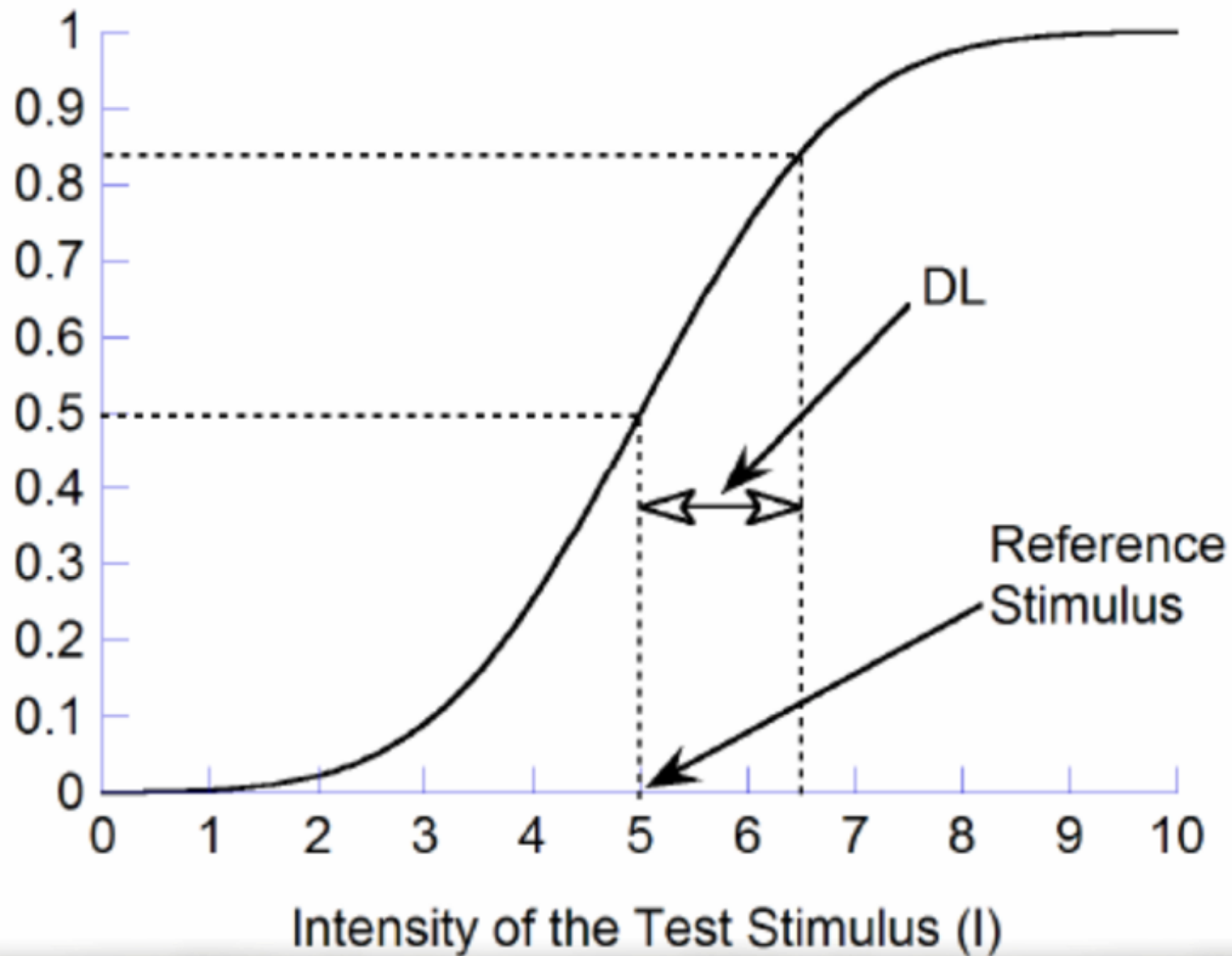
Proportion of Responses "Detected"



Stimulus Intensity (I)

- the absolute threshold is thus the intensity of the stimulus that an observer can barely detect.
- On the other hand, *difference threshold*, refers to the minimum intensity by which a variable *comparison* stimulus must deviate from a constant *standard* stimulus to produce a perceptual difference.

Proportion of Responses "Greater"



How do we determine threshold?

- **Method of Adjustment:**

- the simplest & quickest way to determine absolute & difference thresholds is:

- to let a subject adjust the stimulus intensity until it is just noticed or until it becomes just noticeable (when measuring absolute threshold)
 - or appears to be just noticeably different from or to just match a standard stimulus (when measuring difference threshold).

- **Steps:**
 - the observer is typically provided with a control of some sort that can be used to adjust the intensity, say of a sound, until it just becomes audible. (ascending series)
 - this intensity is recorded to provide an estimate of the observer's threshold.
 - alternatively, the observer can adjust the sound from being clearly audible to just barely inaudible, providing another estimate of the threshold (descending series).
 - Typically the two kinds of adjustments are alternated several times & results are averaged to obtain the threshold estimate.

- **Method of Limits to determine Absolute Threshold**
 - a major difference between the method of adjustment & method of limits is that here one does not allow the observer to control the stimulus directly, rather the experimenter adjusts the intensities.
 - in the method of limits, a single stimulus, say a single light, is changed in intensity in successive, discrete steps and the observer's response to each stimulus presentation is recorded.

- one can start with stimulus which is too weak to be detected, & then increase the intensity in discrete steps till the stimulus is visible (ascending series)
- or one can start from a clearly visible stimulus & then decrease the intensity in discrete steps till the stimulus is not visible (descending series)
- the average of the intensity of the last “seen” & the first “not seen” stimuli in the ascending series & vice-versa in the descending series, is recorded as an estimate of the absolute threshold.

Using the Method of Limits to Determine an Absolute Threshold.

Stimulus Intensity		Response			
	↓		↓		
200			Yes		
180	Yes		Yes		
160	Yes		Yes		
140	Yes	Yes	Yes		
120	Yes	No	No	Yes	
100	Yes	No		No	
80	No	No		No	
60		No		No	
40		No		↑	
20		No			
		↑			
					Mean
Threshold	90	130	130	110	115

Note: In the first series of trials, the experimenter starts with a strong stimulus and decreases its intensity until the observer can no longer detect it. The threshold is the mean of the stimulus intensities that yield the first “no” response and the last “yes” response. In the next series of trials, a weak stimulus is increased in intensity until it is detected. It is customary to start each series at a different stimulus intensity to make it less likely that the observer’s responses will be influenced by the length of a series. Stimuli are in arbitrary units—that is, the intensities ranging from 20 to 200 could represent weight or anything else that might vary in intensity.

- **Method of Limits to determine Difference Threshold**
- difference thresholds are based on relative judgments, in which a constant unchanging comparison stimulus is judged relative to a series of changing stimuli.
- the question that is asked is, “How different must two stimuli be before they can be reliably distinguished?”

- the traditional way to measure is to ask the observer to lift pairs of weights - one constant & the other changing - & to judge if the new weight is heavier, lighter or equal to the standard weight.
- the method is otherwise similar to the last instance:
- one can start from a weight which feels clearly heavier & go till it feels equal & then lighter. or
- one can start from a weight which feels clearly lighter & go till it feels equal & then heavier.

- the upper threshold is the average point at which the observer changes from “heavier” to “equal” &
- the lower threshold is the average point at which the observer changes from “equal” to “lighter”.
- The difference between these two values is called the **interval of uncertainty**.
- The mean of upper & lower thresholds is called the **point of subjective equality**.

Using the Method of Limits to Determine a Difference Threshold.

Comparison Stimulus (grams)		Response			
		↓		↓	
Standard Stimulus	350			Heavier	
	340	Heavier		Heavier	
	330	Heavier		Heavier	
	320	Heavier	Heavier	Heavier	Heavier
	310	Equal	Equal	Heavier	Equal
	300	Equal	Equal	Heavier	Lighter
	290	Equal	Lighter	Equal	Lighter
	280	Lighter	Lighter	Equal	Lighter
	270		Lighter	Lighter	Lighter
	260		Lighter		
					↑
Upper Threshold	315	315	295	315	Mean
Lower Threshold	285	295	275	305	
Interval of Uncertainty = $310 - 290 = 20$ grams					

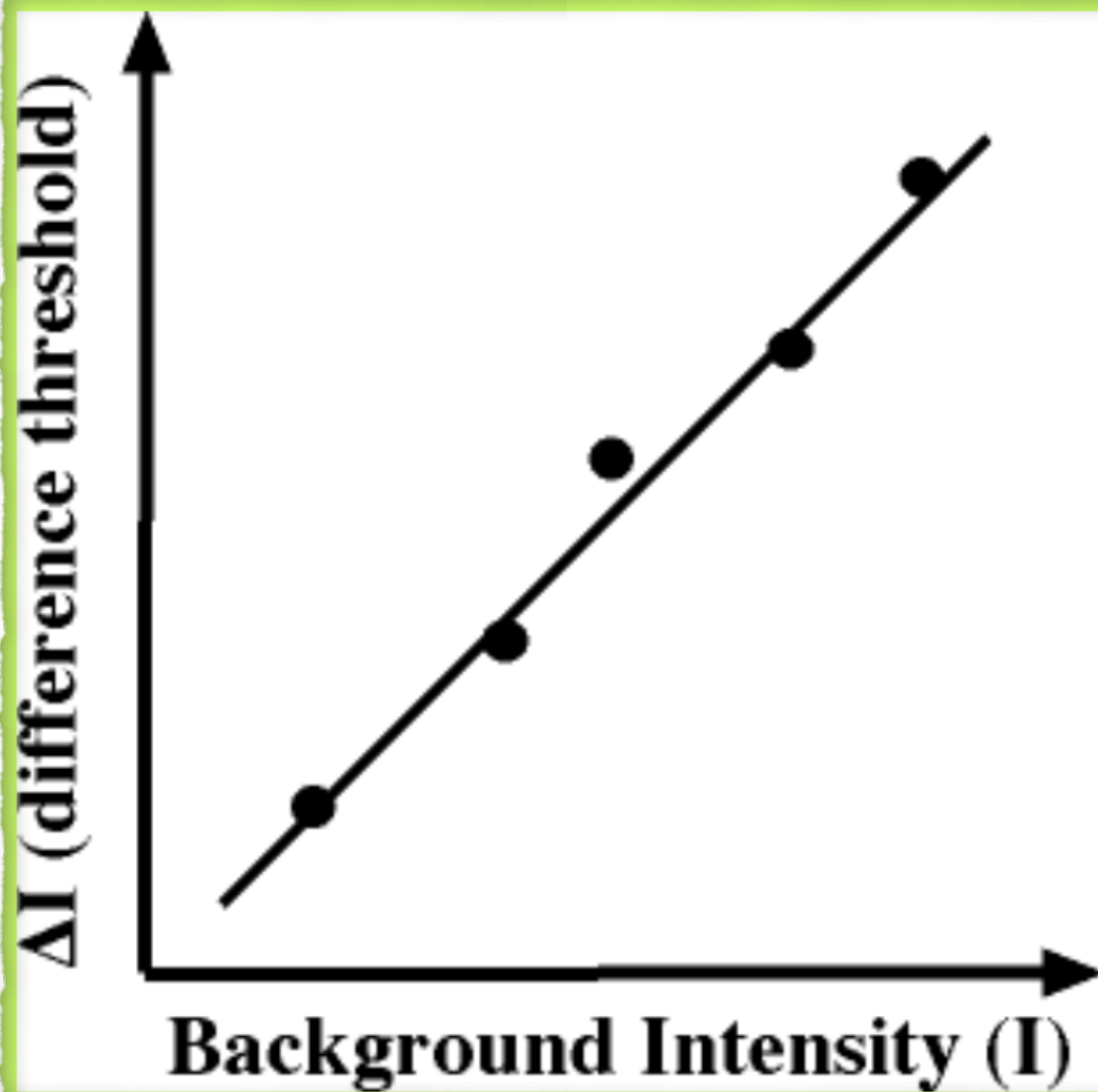
Note: For descending series, the upper threshold is the mean of the stimuli leading to the last "heavier" response and the first "equal" response. The lower threshold is the mean of the stimuli producing the last "equal" response and the first "lighter" response. The standard stimulus is always 300 grams. The difference threshold is one-half of the interval of uncertainty (10 grams, in this example).

Moving Further...

- Ernst Heinrich Weber (1795 - 1878) discovered some important properties of the difference threshold.
 - the magnitude of difference threshold increases with the increase in the magnitude of the standard stimulus.
 - e.g. he found that for a standard weight of 300 grams the difference threshold is 10 grams; while for a standard weight of 600 grams the difference threshold is 20 grams.

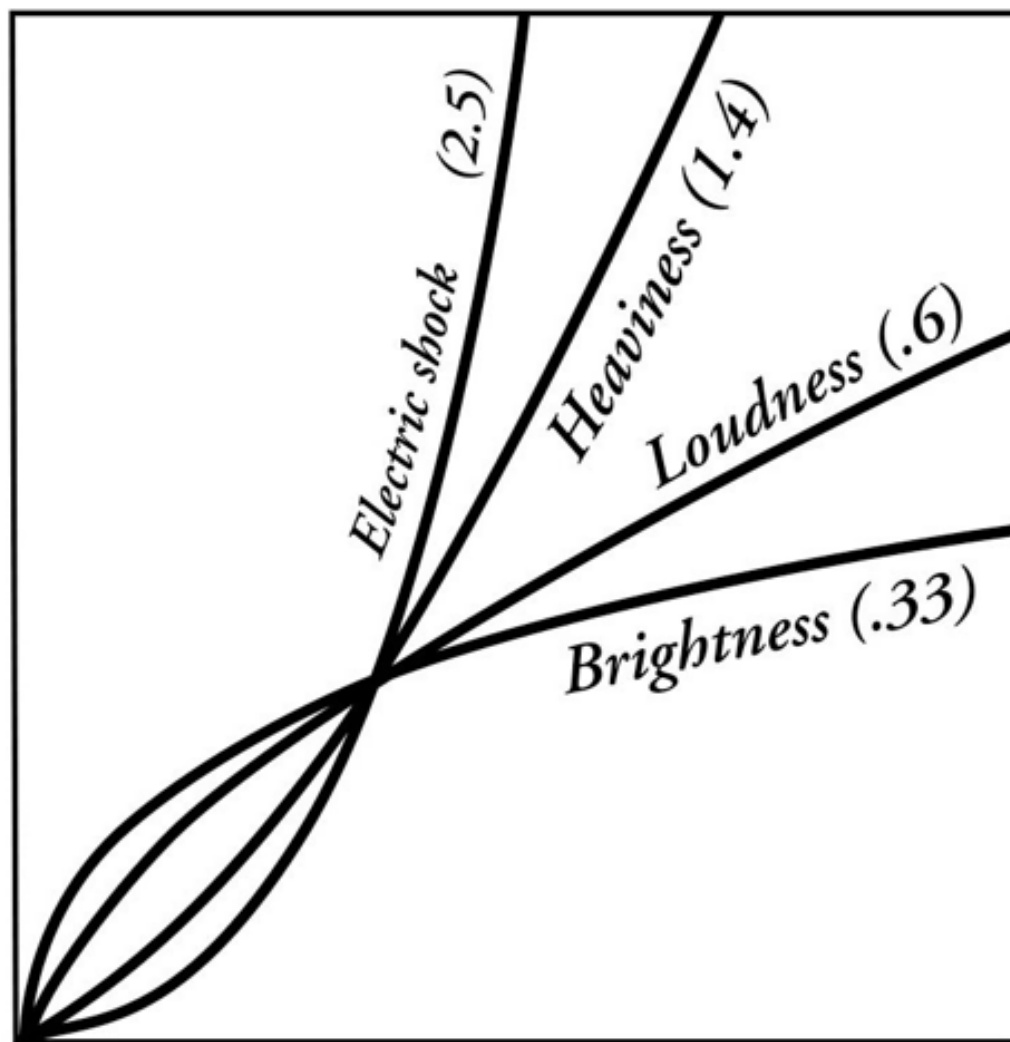
- the second property was, *for a particular sensory modality, the size of the difference threshold relative to the standard stimulus is constant.*
- So, the ratio of 10 grams to 300 grams is the same as that of 20 to 600 grams or 40 to 1200 grams.

- Gustav Fechner called the relative constancy of the difference threshold as **Weber's Law**.
 - **Weber's Law:** $(\Delta I)/I = K$.
- where **I** refers to the magnitude of the standard stimulus, **(ΔI)**, is the difference threshold, & **K** is the symbol for constancy.



- Weber's Law or Weber Fraction varies in size for different senses. for e.g. it is somewhat larger for brightness than it is for heaviness.
- Weber also discovered that the value of the difference threshold is about 2% of the magnitude of standard stimulus intensity.

Magnitude Estimate



Stimulus Intensity

- **Method of Constant Stimuli**

- here, the experimenter chooses a number of stimulus values (usually from 5 to 9 values) which, on the basis of previous exploration are likely to encompass the threshold value.
- this fixed set of values is presented multiple times in a quasi - random order that ensures each will occur equally often.

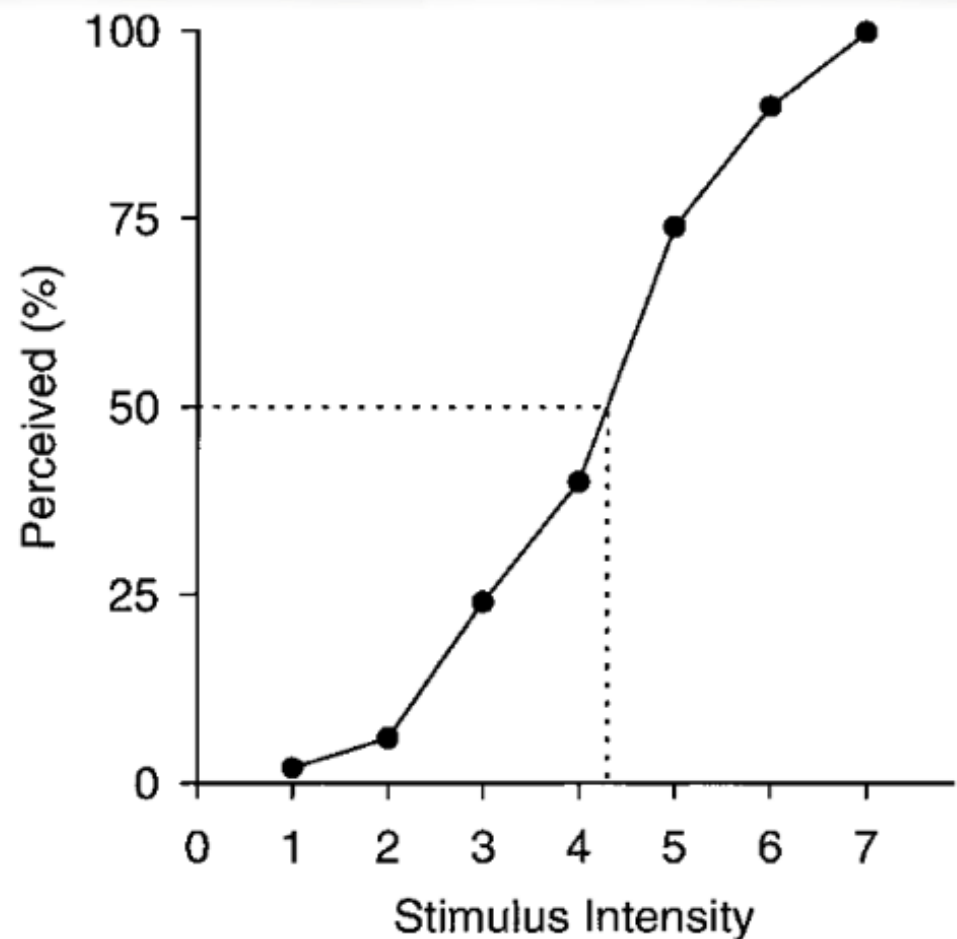
- after each stimulus presentation, the observer reports whether or not the stimulus was detected (absolute threshold) or whether its intensity was weaker or stronger than that of a standard (difference threshold).
- once each value has been presented multiple times (~20), the proportion of “detected” & “not detected” (“weaker” or “stronger”) responses is calculated for each stimulus level.

- the data are then plotted with stimulus intensity along the x-axis & the percentage of perceived stimuli along the y-axis.
- the resulting graph represents the so called **psychometric function**.

Table 2. Method of Constant Stimuli (50 Presentations for each Stimulus Intensity)

Stimulus Intensity (arbitrary units)	1	2	3	4	5	6	7
Frequency of Perceived Stimuli	1	3	12	20	37	45	50
Percentage of Perceived Stimuli	2	6	24	40	74	90	100

Fig. 3. Psychometric function which shows the relationship between the percentage of times that a stimulus is perceived and the corresponding stimulus intensity. The threshold is defined as the intensity at which the stimulus is detected 50 percent of the time.



- Note that, if there were a fixed threshold for detection, the psychometric function should show an abrupt transition from “not perceived” to “perceived”.
- however, psychometric functions are generally Sigmoidal (S- shaped) curves, that reflect that lower stimulus intensities are detected occasionally and higher values more often; intensities in the middle are detected sometimes & sometimes not.

- other reasons why we get a S-shaped curve here could be the continuous fluctuations in the sensitivity of the various biological systems (due to spontaneous activity or internal noise).
- these inherent fluctuations mean that an observer must detect activity elicited by external stimulation against a background level of activity.

- so, the threshold occurs with a certain probability and its intensity value must be defined statistically.
- by convention, the absolute threshold measured with the method of constant stimuli is defined as the intensity value that elicits “perceived” responses on around 50% of the trials.
- in Table 2., this comes between levels 4 & 5.

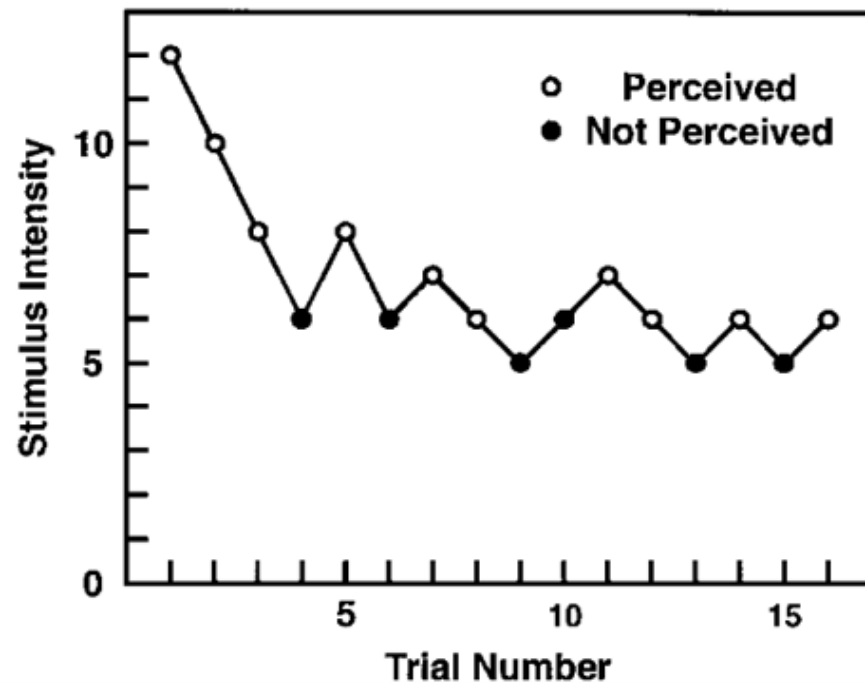
- **Staircase Method**

- adaptive testing procedures are used to keep the test stimuli close to the threshold by adapting the sequence of stimulus presentations according to the observer's response.
- since a smaller range of stimuli need to be presented, such methods are more efficient. an example being the **staircase method**.

- the staircase method is a modification of the Method of Limits.
- an observer may start from an ascending or descending series of stimuli.
- each time the observer says “yes” the intensity is changed (increased/decreased) by one step.
- this continues until the stimulus becomes too weak to be detected.
- at this point, we reverse the direction of the series by one step; & continue till the response changes from “yes” to “no” or vice-versa.

- usually six to nine such reversals are taken to estimate the threshold, which is defined as the average of all the stimulus intensities at which the observer's response changed; i.e. the transition points.

Fig. 4. Adaptive testing technique using a single staircase procedure. This example shows a descending staircase for which stimulus intensity is decreased when the stimulus is perceived and increased when it is not perceived.



To Sum Up

- We talked about the concept of sensation vs. perception.
- We also talked about how abstract experiences can be quantified using psychophysics.
- We also talked about the various possible methods in psychophysics that are used to put numbers to sensations.