



# Psychophysical Methods

## First Lesson

*Monica Gori*

# Course Outline

- What is Psychophysics?
- History and example experiments
- Concept of threshold
- Absolute Threshold + examples
- Differential Threshold + examples
- Classical Psychophysical Methods with experiments examples.
- Methods of constant stimuli + examples
- Methods of adjustment + examples
- Methods of limits + examples
- Signal Detection Theory
- How to design an experiment

# Today Lesson's Outline

- *What is Psychophysics?*
- *Concept of Sensation*
- *Is perception veridical?*
- *History of Psychophysics*
- *Sensory Threshold*
- *introduction to Absolute Threshold*
- *introduction to Differential threshold*
- *Sensation dimensions*
- *Weber's law*
- *Concept of Noise*
- *Fechner's law*

# Textbook

- Psychophysics the fundamentals, George A. Gescheider

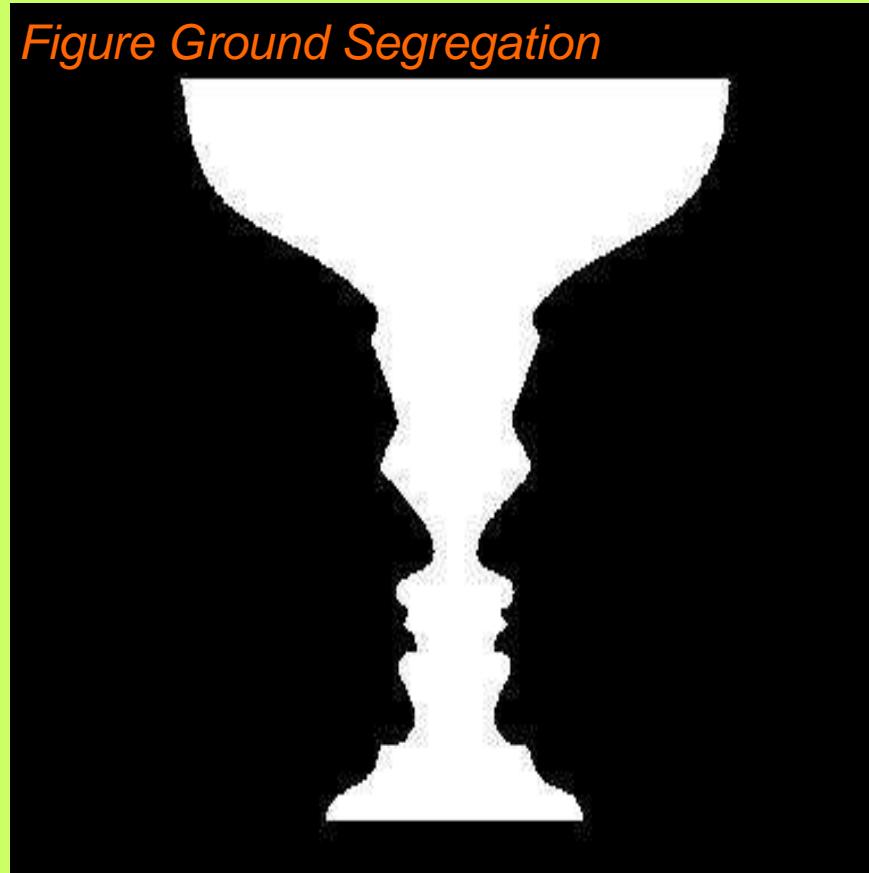
# What is Psychophysics?

- *Definition*

- Psychophysics investigate the relationship between sensation ( $\psi$ ) in the psychological domain and stimuli ( $\Phi$ ) in the physical domain
- It refers to the methodology of studying perception (designing experiments, formulating models)

# Do we all perceive things the same way?

*Figure Ground Segregation*



*Glass Patterns Movie*

# Sensation

- For centuries thinkers have recognized the importance of understanding sensation in order to answer many questions like for examples:
  1. *Is the perception an active or a passive process?*
  2. *Is perception veridical?*
  3. *Can perceptual mechanisms be modified?*
  4. *Can we integrate different signals from different sensory modalities?*

# 1. Is the perception an active or a passive process?

- Do I only receive and elaborate information from the external environment or can I also use these signals in order to interpret future ones?
- Is the perception an active or a passive process?

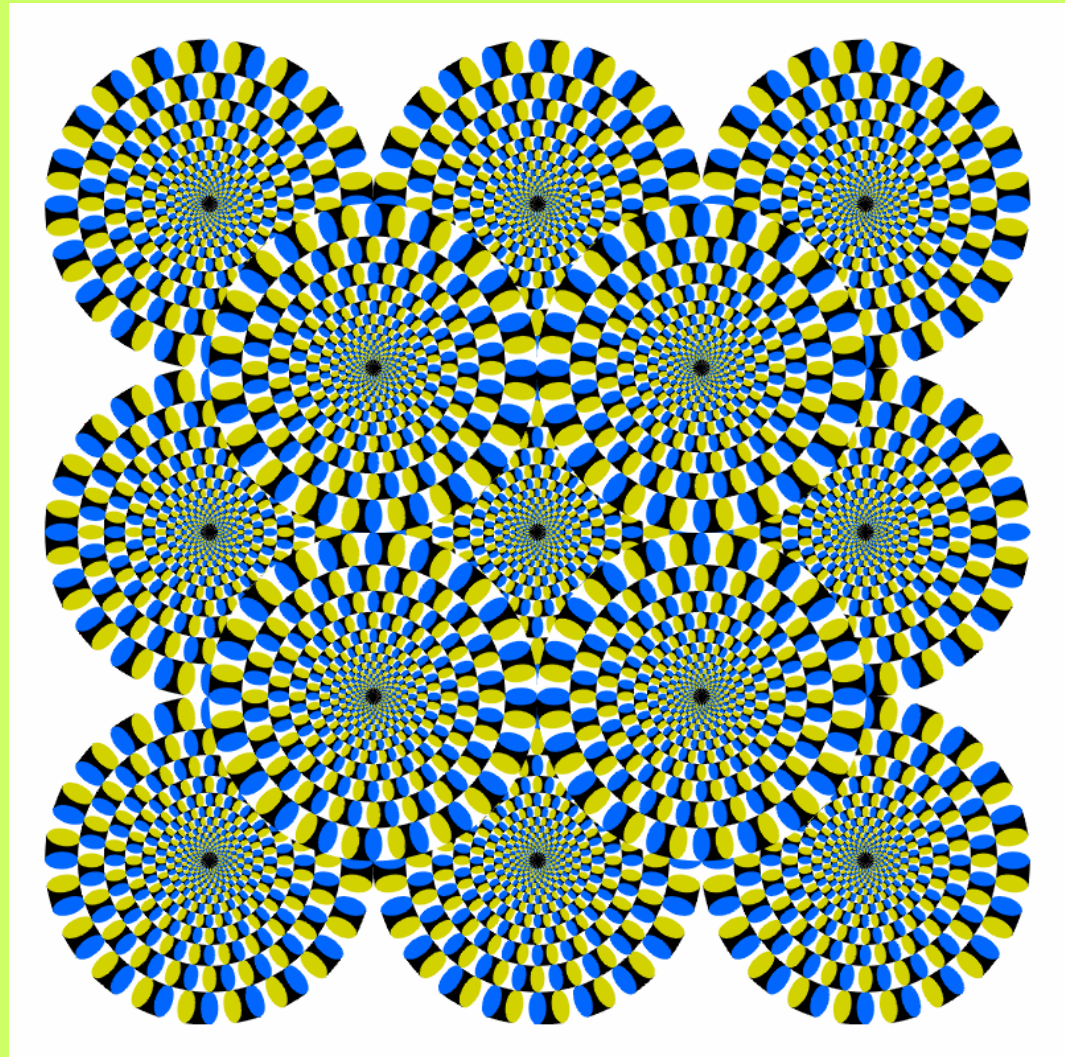




## 2. Is perception veridical?

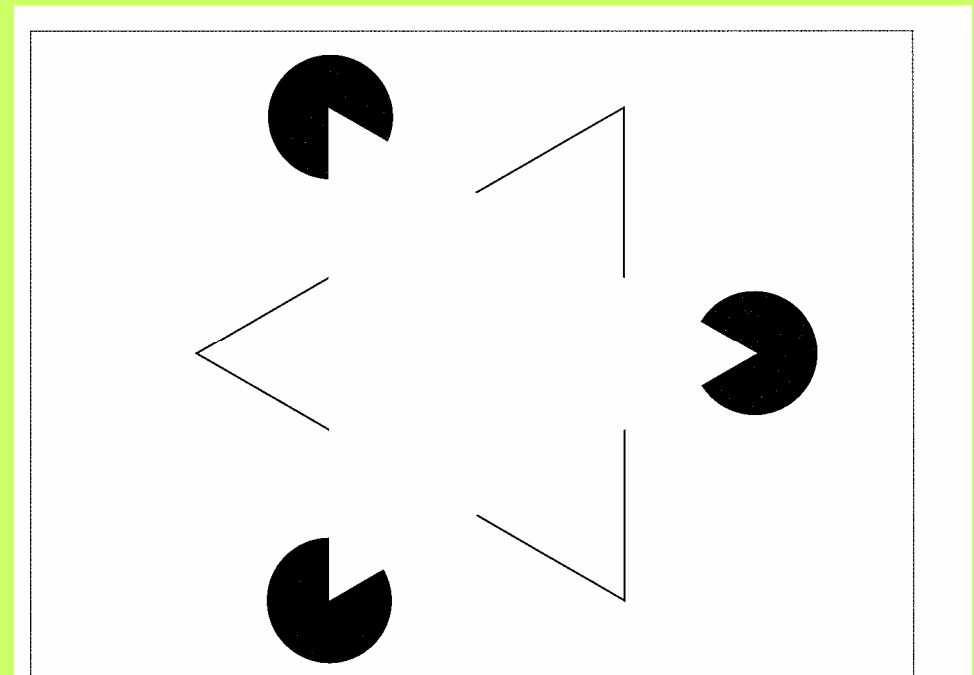
- Do the perception reflect the physical stimulus or it is not veridical?

Glass-Anti Glass Patterns Movie



## 2. Is perception veridical?

- Do the perception reflect the physical stimulus or it is not veridical?
- Are these signal conscious to myself or not?



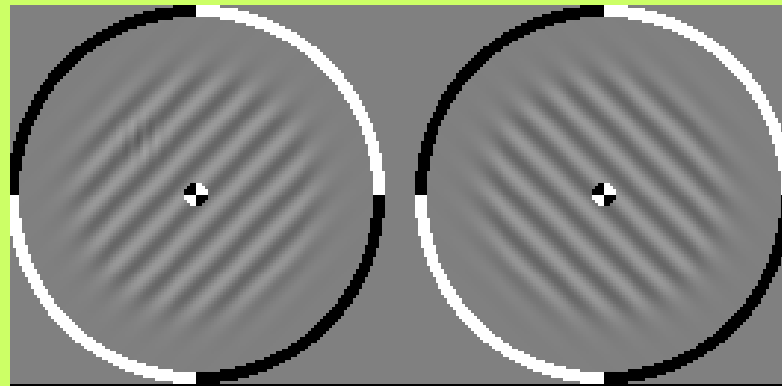
### 3. Can perceptual mechanisms be modified?

#### Motion aftereffects (demo)

- The mechanisms of motion aftereffects are well understood. The brain has a variety of neurons that detect motion in a particular direction.
- If some motion detectors continuously respond to motion for a while, they tire or adapt to that motion and become less active.
- When the motion is stopped, different motion detectors, especially those for the opposite direction, become active, and give rise to the illusory motion in that direction.

# Do we all perceive things the same way?

## *Binocular Rivalry*



**If the two eyes see very disparate images, like in this stereogram, humans experience binocular rivalry: after a short time-delay during which one sees both images superimposed, perception then alternates in a random fashion between the left and right view of the scene.**

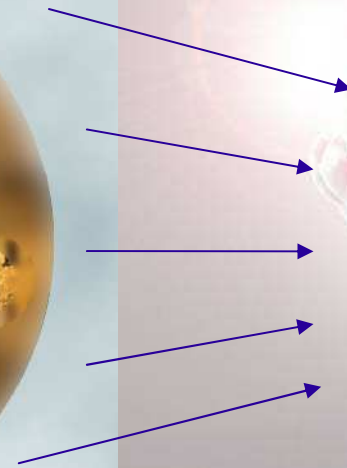
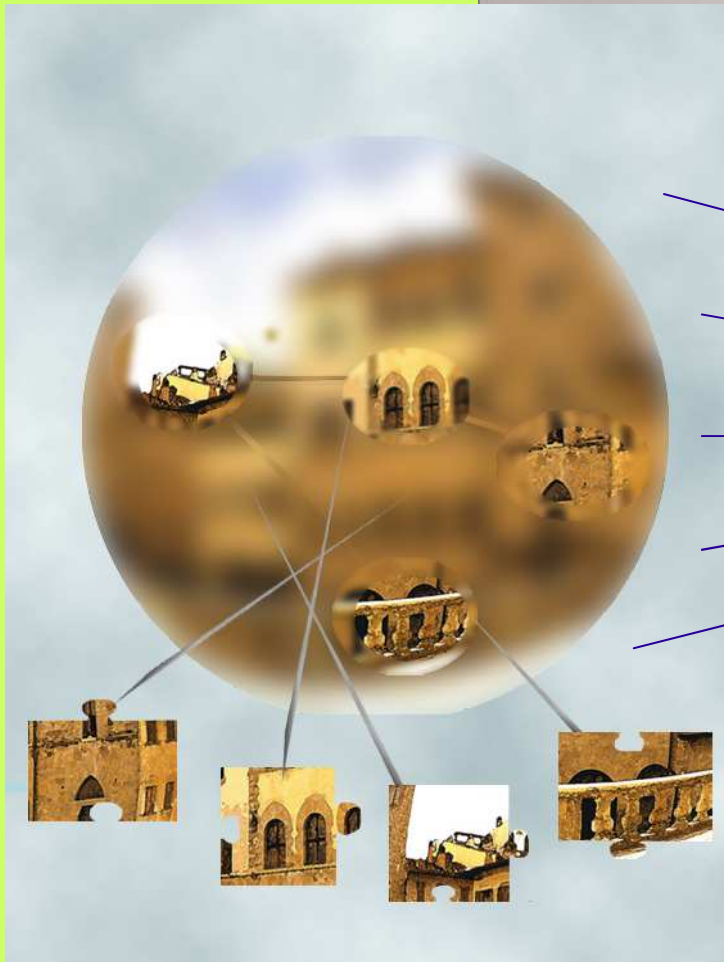
## 4. Can we integrate different signals from different sensory modalities?

*Visual*

*Auditory*

*Haptic*

*Others.....*



# Sensory fusion

No information-processing system is powerful enough to 'perceive and act' accurately under all conditions.

The key to robust perception is the combination and integration of multiple sources of sensory information.



# Sensory Combination

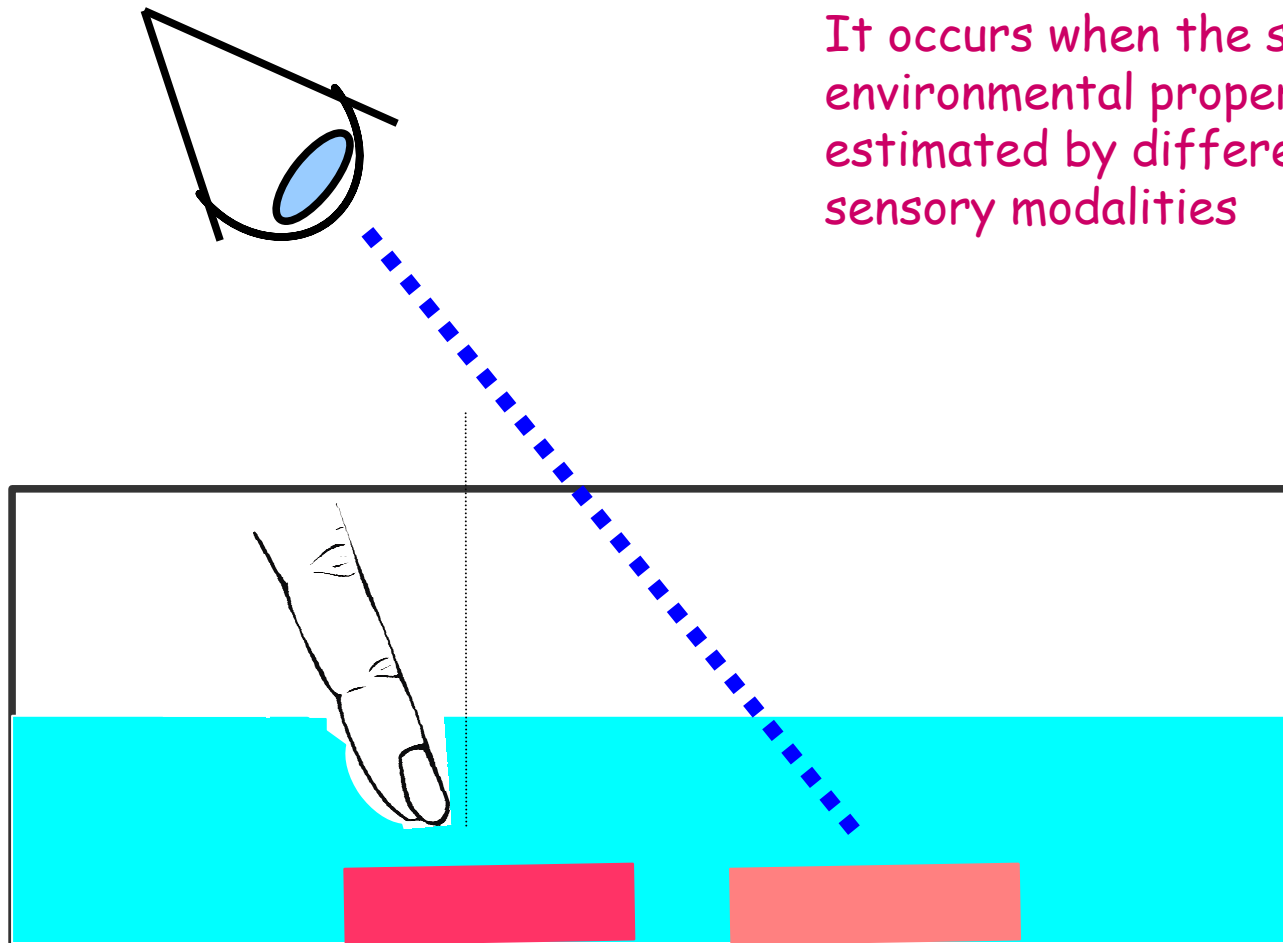


Visually:  
contrast  
color.....

Haptically:  
weight  
temperature....

It occurs when different  
environmental properties  
of the same object are  
estimated by different  
sensory modalities

# Sensory Integration



It occurs when the same environmental property is estimated by different sensory modalities



# Cross Modal interaction integration and combination

- ***Smarties Effect.***

*“Assessing the Role of Color Cues and People's Beliefs About Color–Flavor Associations on the Discrimination of the Flavor of Sugar-Coated Chocolates”* Carmel A. Levitan<sup>1</sup>, Massimiliano Zampini<sup>1,2,3</sup>, Ryan Li<sup>1</sup> and Charles Spence *Chemical Senses* 2008 33(5):415-423; doi:10.1093/chemse/bjn008

- ***McGurk effect***

- ***Ventriloquist Effect***

- ***Flash tap Effect***

# McGurk effect (demo)

- Can perceptual modalities interact?

The McGurk effect (named after Harry McGurk of McGurk & McDonald, 1976) is a compelling demonstration of how we all use visual speech information. The effect shows that we can't help but integrate visual speech into what we 'hear'.

# The “*ventriloquist effect*”

Previous explanations of ventriloquist effect

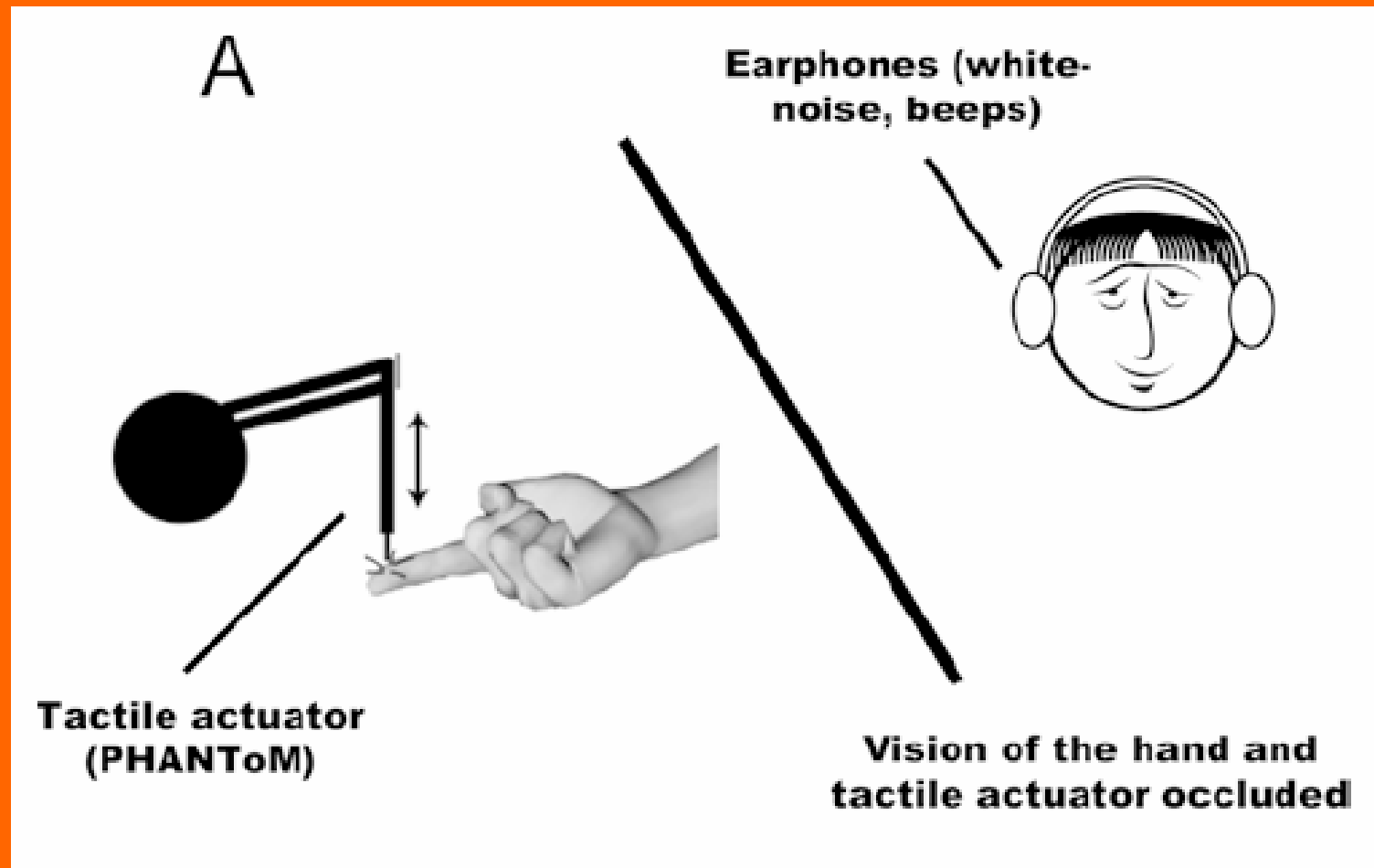
- Magic.
- Vision “captures” sound: inherent dominance of vision.



Example of ventriloquist effect

Alais and Burr *Current Biology* 2004

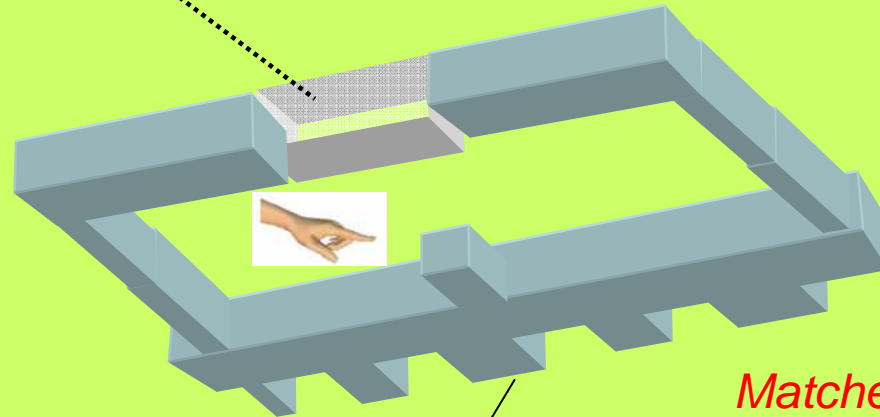
## Feeling what you hear: auditory signals can modulate tactile tap perception



# Rock & Victor Experiment (1960)

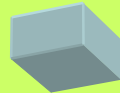


*The Lens introduce  
a Visual Haptic Conflict*



*Matched with visual size:  
Vision Dominates*

***Visual  
perception***



***Haptic  
perception***



# Unimodal domination

- **Visual-audio domain:** Shams et al. (2002) showed that when a **single visual flash** is accompanied by **multiple** task irrelevant **auditory beeps**, the single flash is **perceived as multiple flashes**.
- **Audio-tactile domain:** Hötting and Röder (2004) and Bresciani et.al (2004) found that **one tactile tap** accompanied by **multiple auditory tones** is **perceived as more than a single tap**.

# Unimodal Dominance

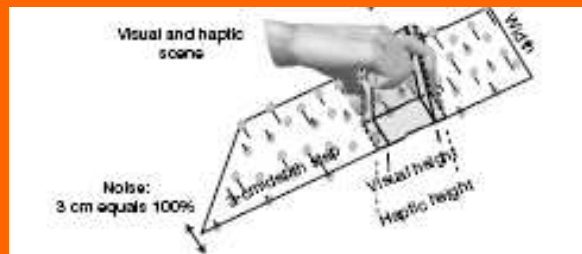
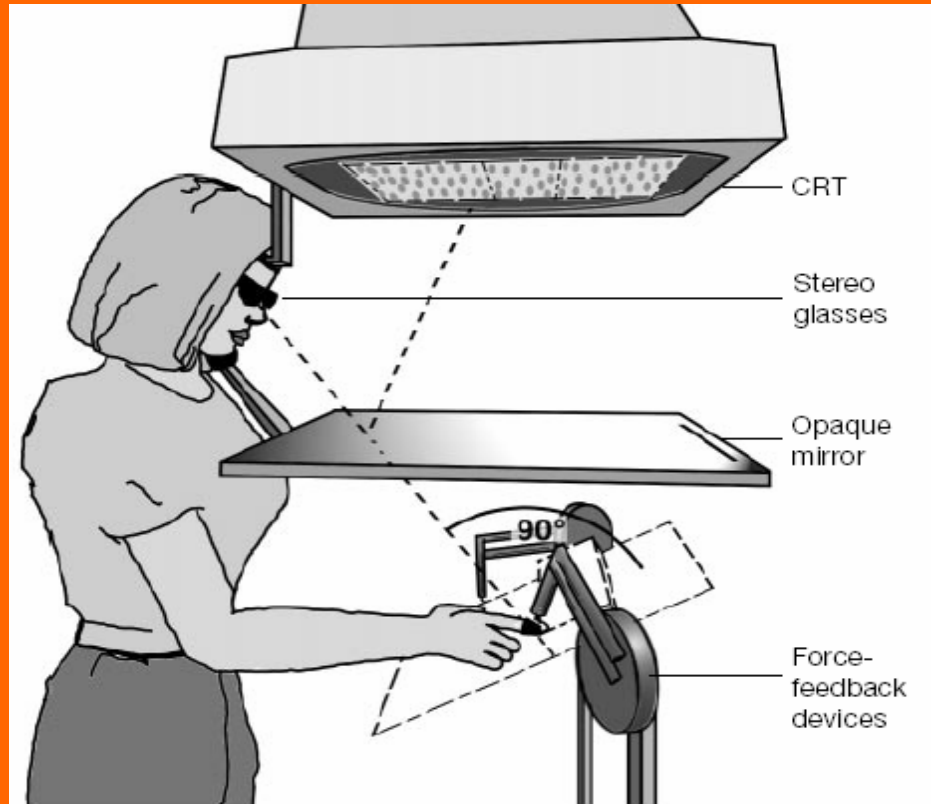
- Auditory system dominates in the temporal domain
- Visual system dominates in the spatial domain (i.e. shape, size or position)

Is it a real dominance or is it possible that both modalities somehow contribute to the final percept?

# Humans integrate visual and haptic information in a statistically optimal fashion

Marc O. Ernst e Martin S. Banks Nature Vol 415 January 2002

To quantify the multimodal integration across senses



Optimal combined estimate of size

$$\hat{S}_{VH} = w_H \hat{S}_H + w_V \hat{S}_V$$

$$w_i = \frac{1/\sigma_i^2}{\sum_j 1/\sigma_j^2}$$

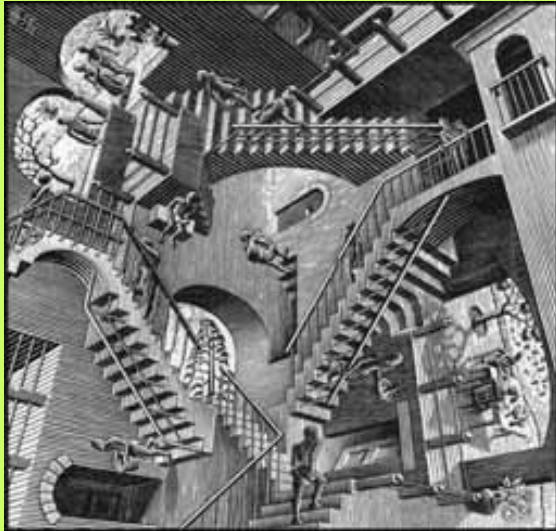
Improvement of threshold

$$\sigma_{VH}^2 = \frac{\sigma_V^2 \sigma_H^2}{\sigma_V^2 + \sigma_H^2}$$

Virtual Reality



# Illusions and Art



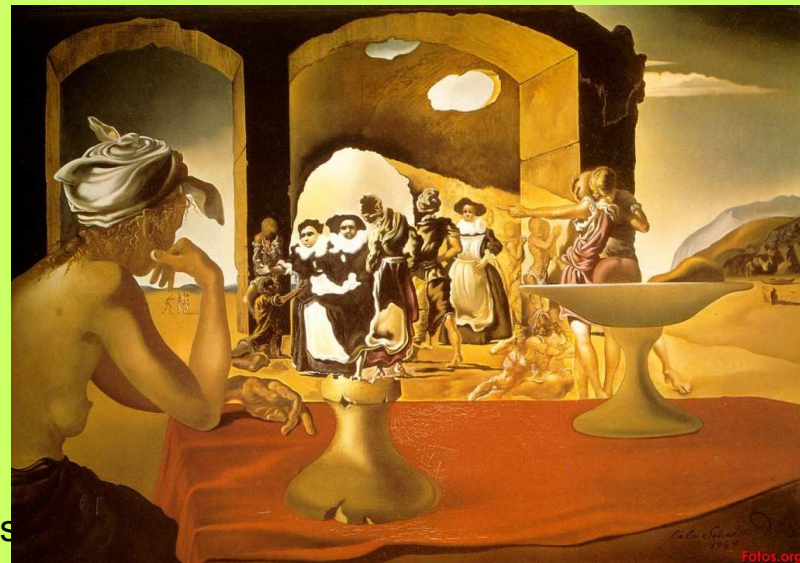
Relativity *of Escher*



Forever Always *of Octavio Ocampo*



"Not to be Reproduced" *of René Magritte*



Disappearing Bust of Voltaire *of Salvador Dalí*

# History

- **The problem of psychophysics constitute some of the most fundamental problems of modern psychology.**
- **Prior of a century ago the approach to psychological problems consisted primarily of philosophical speculation.**

# History

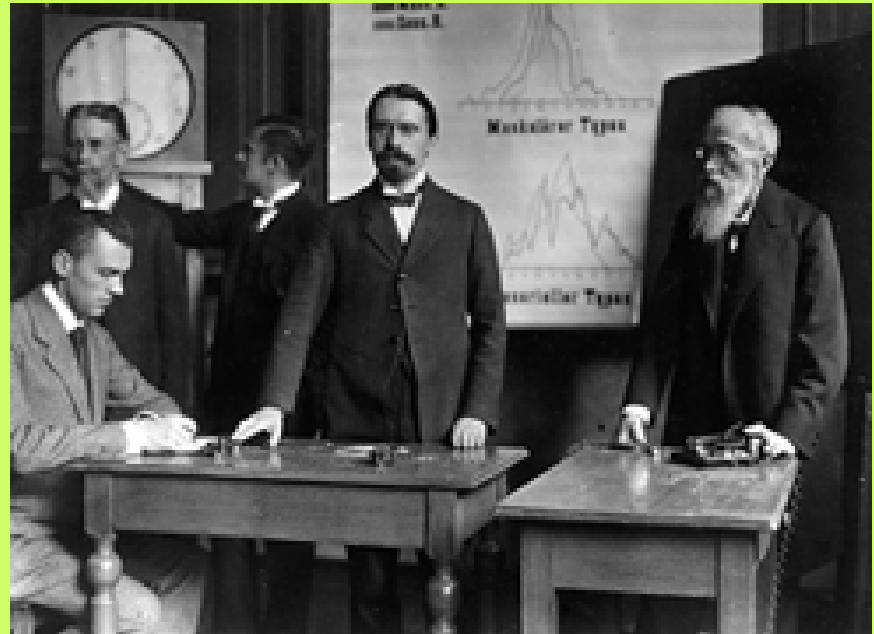
- The transition of psychology from philosophical to a scientific discipline was facilitated when G. T. Fechner introduced techniques for measuring mental events.
- In 1860 Fechner published “Elements of psychophysics” where provide methods and theory for the measurement of sensation.



Fechner

# History

- Experimental psychology was established as an independent sciences when Wundt (1879) founded the first laboratory for experimental work exclusively directed toward understanding psychological processes.
- The work of Wundt evolved from British empiricist and associationist schools of philosophy that establish the idea that senses are the key to human understanding. This idea was reinforced by advances in sensory physiology.



**Wundt in the Laboratory at Leipzig**

# Principal Problem

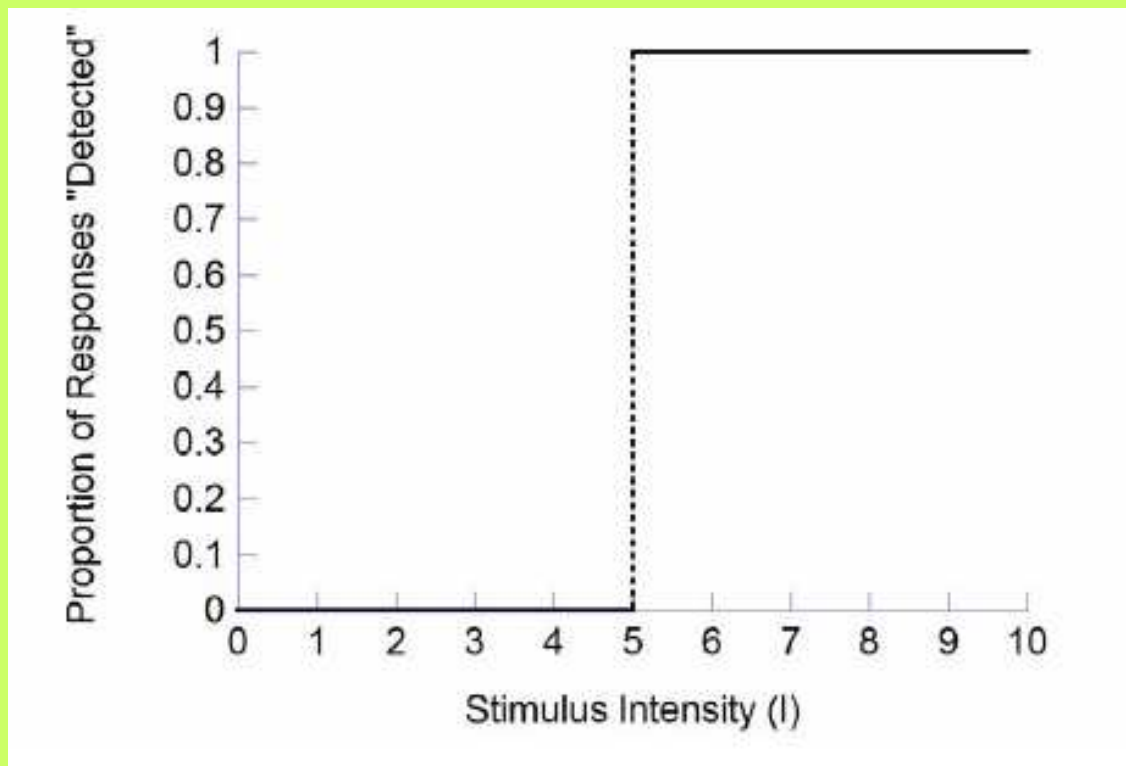
- **How to establish the relation between perceptions and the underlying brain mechanisms?**
- **The goal of perception is to acquire accurate and reliable information about the environment.**

# Sensory Threshold

- The central concept of Psychophysics is that of *sensory threshold*.
- “Mental events had to be stronger than some critical amount in order to be consciously experienced” Herbart (1824)
- Weber and Fechner were interested in the measurement of the sensitivity limits of the human sense organs.
- Using measurement techniques of physics and well trained human observers, were able to specify the weakest detectable sensation in terms of stimulus energy necessary to produce them.

# Absolute Threshold

- The absolute threshold was defined as the smallest amount of stimulus energy necessary to produce a sensation.

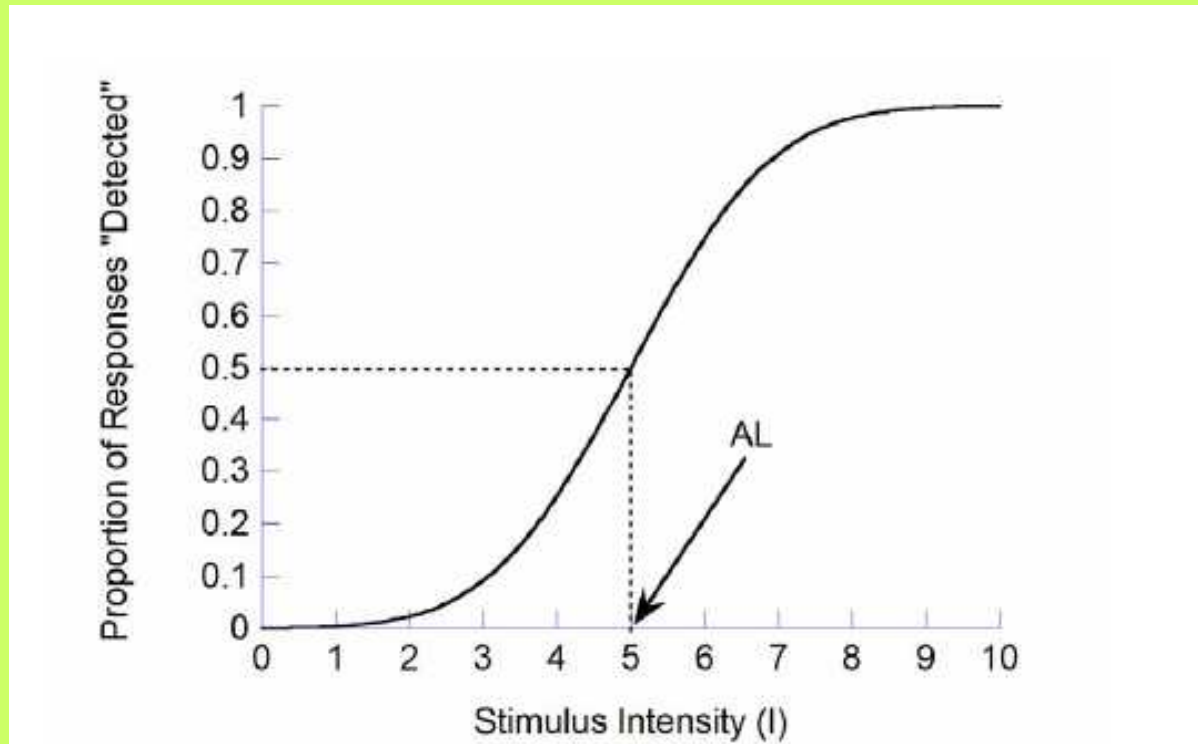


# Absolute Threshold

- Since an organism's sensitivity to external stimuli tends to fluctuate somewhere from moment to moment, several measurements of the threshold value of the stimulus are averaged to arrive an accurate estimation of absolute threshold.



# Absolute Threshold



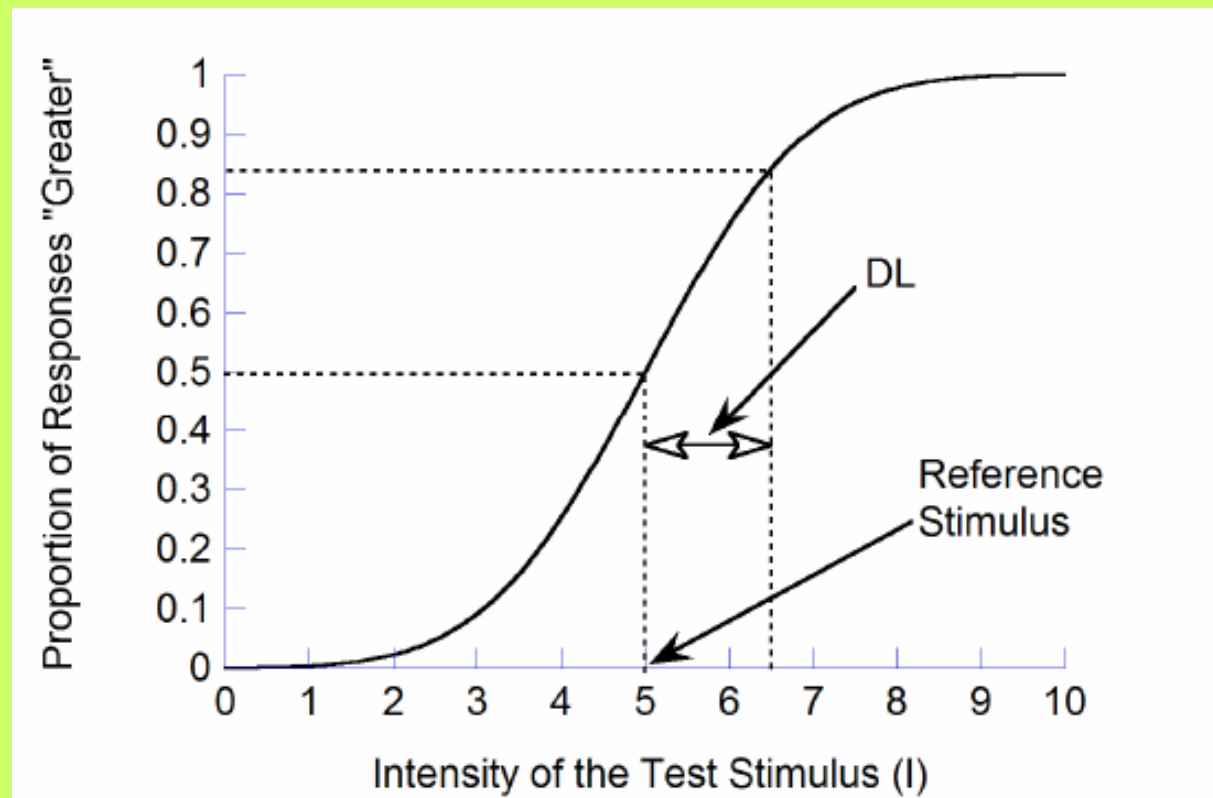
- Perceptual representation of a stimulus is not constant; it involves an additive random error. It follows that the psychometric function is not a step-function. Instead it is an S-shaped curve.
- AT is defined as the 50<sup>th</sup> percentile point

# Differential threshold

- When a stimulus above absolute threshold is applied to the sense organ, the intensity of the stimulus must be increased or decreased by some critical amount before a person is able to report any change in sensation.

# Differential Threshold

Difference threshold is the smallest difference between two stimuli that can be reliably detected



# *Just noticeable difference*

- The difference threshold was defined as the amount of change in a stimulus ( $\Delta \Phi$ ) required to produce a *just noticeable difference* (*jnd*) in the sensation.
- *Intensity stimulus=10 units*
- *Stimulus must be increased to 12 units to produce a just noticeable increment in the sensation*
- *Difference threshold=2 units*

# Sensation dimensions

Intensity isn't the only way in which sensation can differ.

Sensation can differ an at least four basic dimensions:

- Intensity
- Quality
- Extension
- Duration

# Sensation dimension: quality

- ✓ Between modalities, kind of sensation (seeing different from hearing)
- ✓ Within the same modality (higher or lower sound, variation in wavelength of light, cutaneous sensation: pain warmth, cold, pressure)

# Sensation dimension: extension

- By varying along the dimension of extension, the DT can be measured for variation in spatial aspect of the physical stimuli such as:
  - ✓ Size
  - ✓ Location
  - ✓ Separation

# Sensation dimension: duration

- Since sensation last for varying periods of time, the DT was measured for different duration of the stimulus.



# Differential threshold

- Differential threshold is measured for example for:
  - ✓ Auditory pitch discrimination for changes in frequency
  - ✓ Colour discrimination for the perception of changes in the wavelength of light

# Work in Psychophysics

- Much work in Psychophysics has consisted of investigating how absolute and difference thresholds change as some aspect of the stimulus is varied (wavelength, frequency, adaptation, time, intensity, level, etc.)
- The resulting relations are called stimulus critical value functions, since they describe how the threshold changes as a function of other aspects of the stimulus.
- Psychophysical experiments allow making inferences about *many* aspects of perception.

# Weber's law

Relation between the difference threshold for intensity and the intensity level of the stimulus:

i.e. Difference threshold=2 units

if intensity level of the stimulus=10 units

*And when the intensity level of the stimulus=20,30,40 or 50 units?*

# Weber's law

- Weber (1834) discover that the size of the difference threshold was linear function of the stimulus intensity

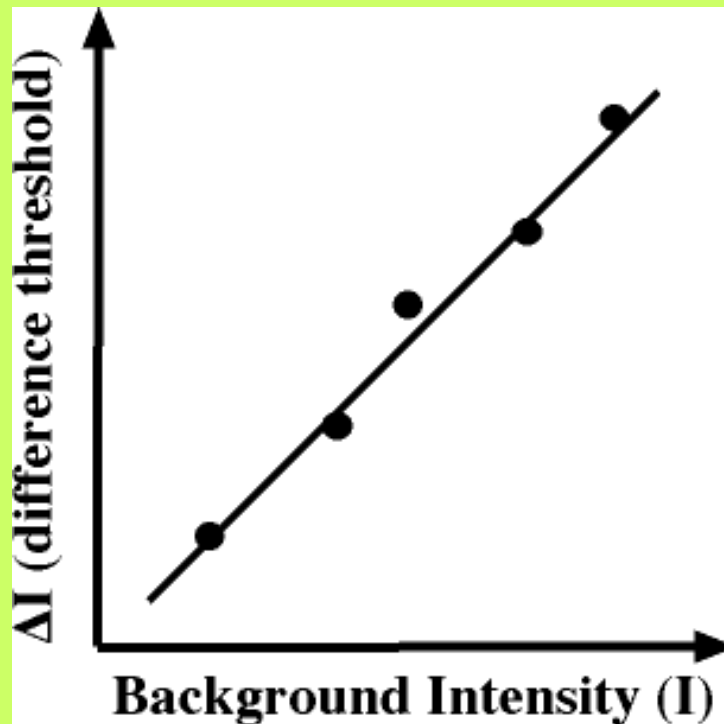
*Weber 's law: the change in the stimulus intensity that can just be discriminated ( $\Delta\Phi$ ) is a constant fraction ( $c$ ) of the starting intensity of the stimulus ( $\Phi$ )*

$$\Delta\Phi=c\Phi \quad \text{or} \quad \Delta\Phi/\Phi=c$$

- Thus, increases in the intensity of the stimulus that were just noticeably different to the observer were always a constant fraction of the stimulus intensity.

# Weber's law

- Below is a plot of some hypothetical data showing Weber's Law. The slope of the line is the Weber fraction.



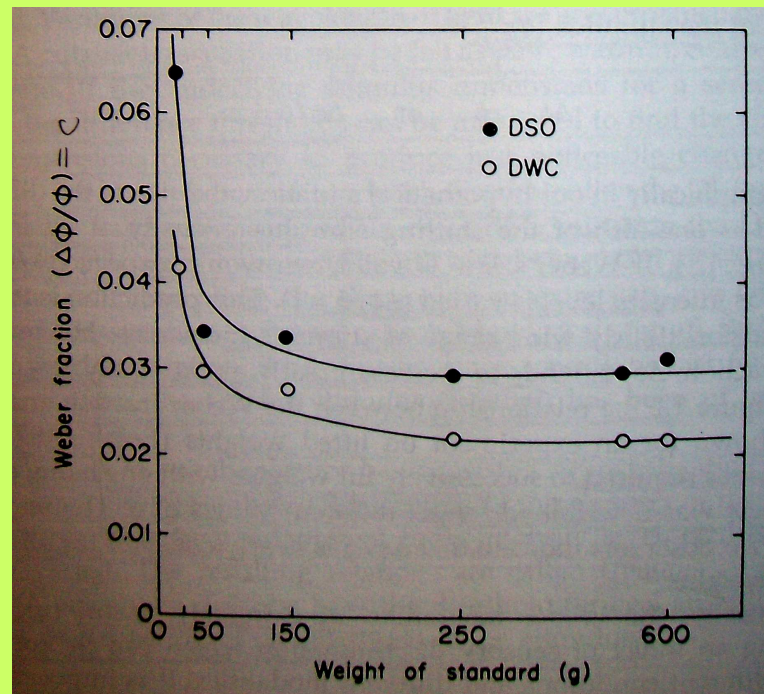
$$\Delta\phi / \phi = c$$

For a fairly wide range of stimulus intensities

# Weber's law

- *Whether the stimulus is applied to eye, skin, nose, tongue or other senses there is a lawful relationship between the size of the difference threshold and the stimulus intensity level.*
- valid for a wide range of stimulus intensities
- it is good as a baseline to compare performance
- not always true->increase greatly at extremely low stimulus intensities.

# Weber's law



Weber fraction for lifted weights. For 2 observers was nearly constant over the stimulus range, except for the lowest stimulus values (Engen 1971)

# Weber's law

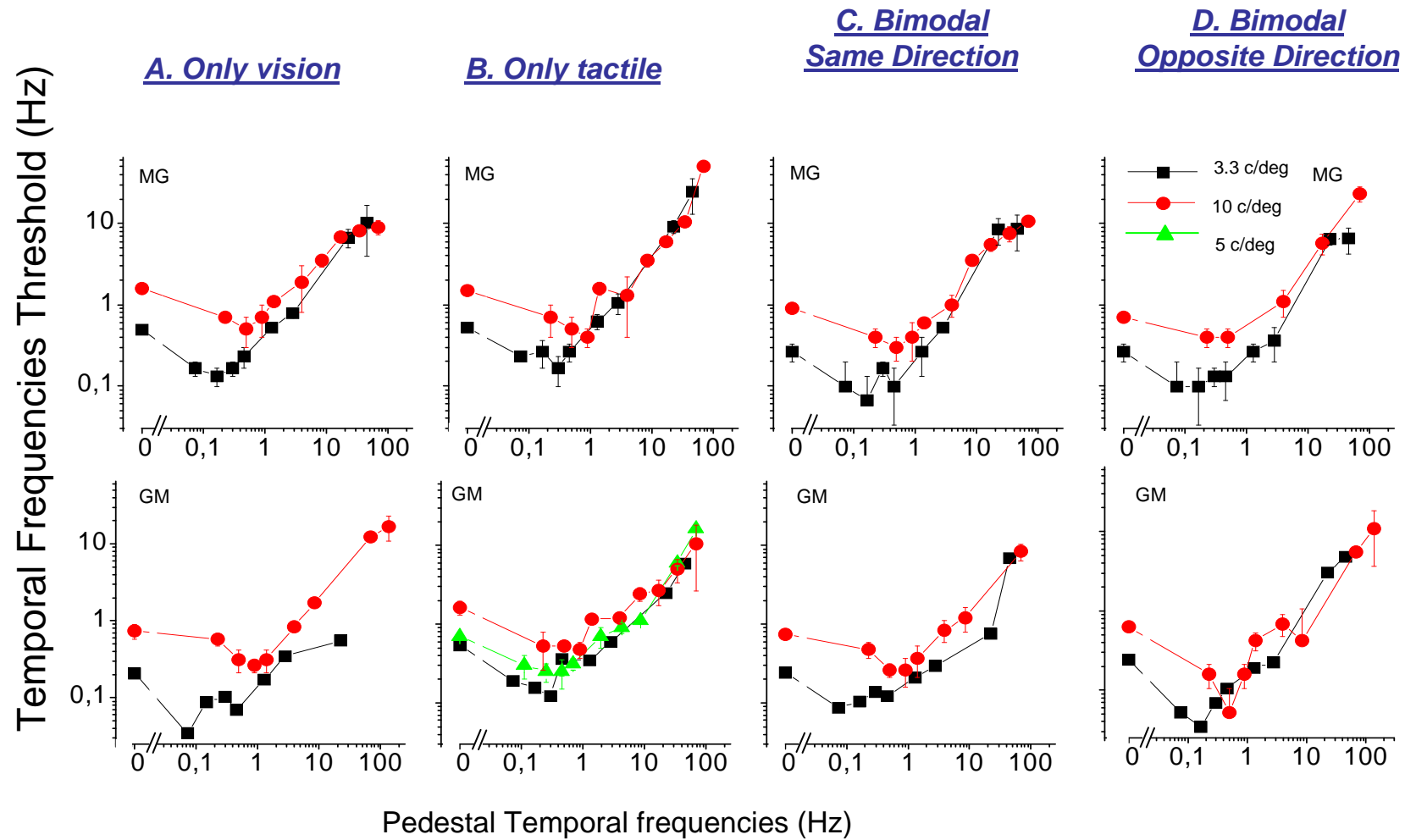
- Weber fraction provide an index of sensory discrimination that can be compared over different conditions and different sensory modalities.
- i.e. you can't compare  $\Delta\Phi$  for vision in luminosity units with  $\Delta\Phi$  for audition in sound pressure units but you can compare the two modalities through the weber fraction comparison



# Ongoing experiment

- Now we will try to measure discrimination threshold for visual and haptic modalities by varying our stimulus intensity.
- Two group will evaluate the visual discrimination thresholds for base stimulus intensities of 5-6-7 cm.
- Two group will evaluate the haptic discrimination thresholds for base stimulus intensities of 5-6-7 cm.
- Then we will extract the Weber's law for each group and each modality and we will compare them.

# Weber's law and dipper function



# Modification of Weber's law

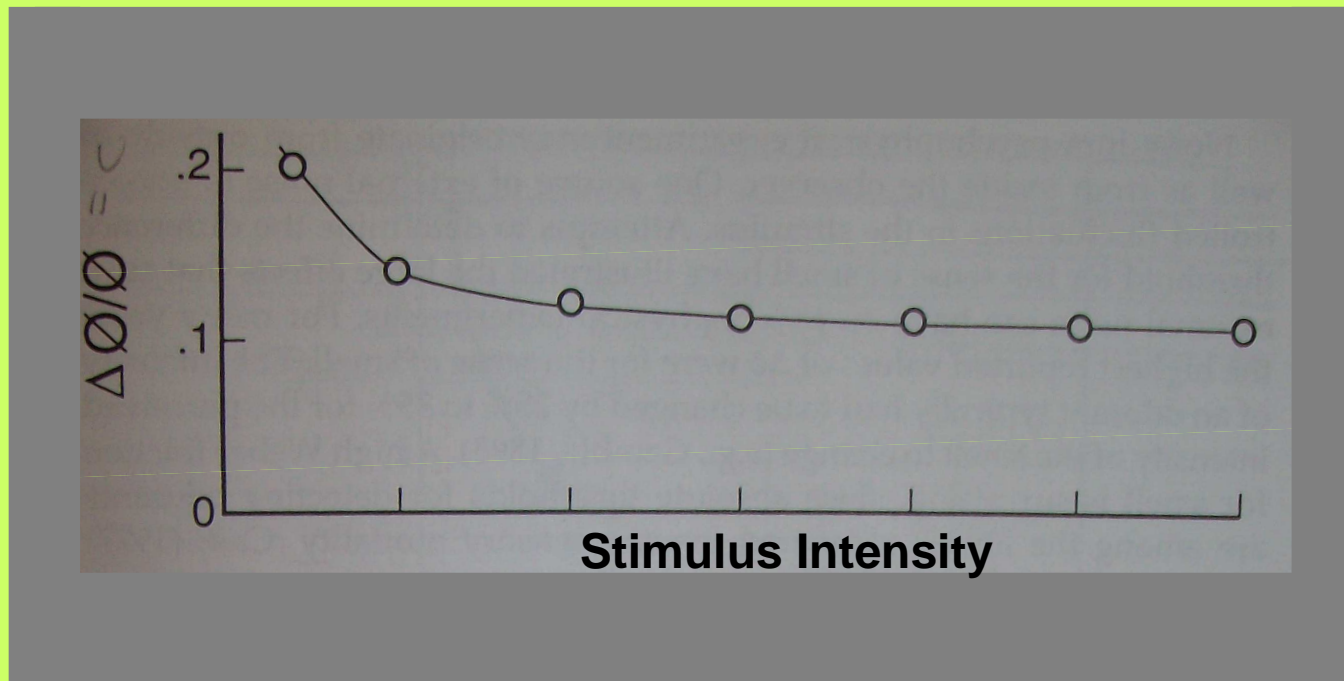
- A modification of Weber's law more closely corresponding to empirical data states:

$$\Delta\Phi/(\Phi+a)=c$$

Where  $a$  is a constant that usually has a fairly small value

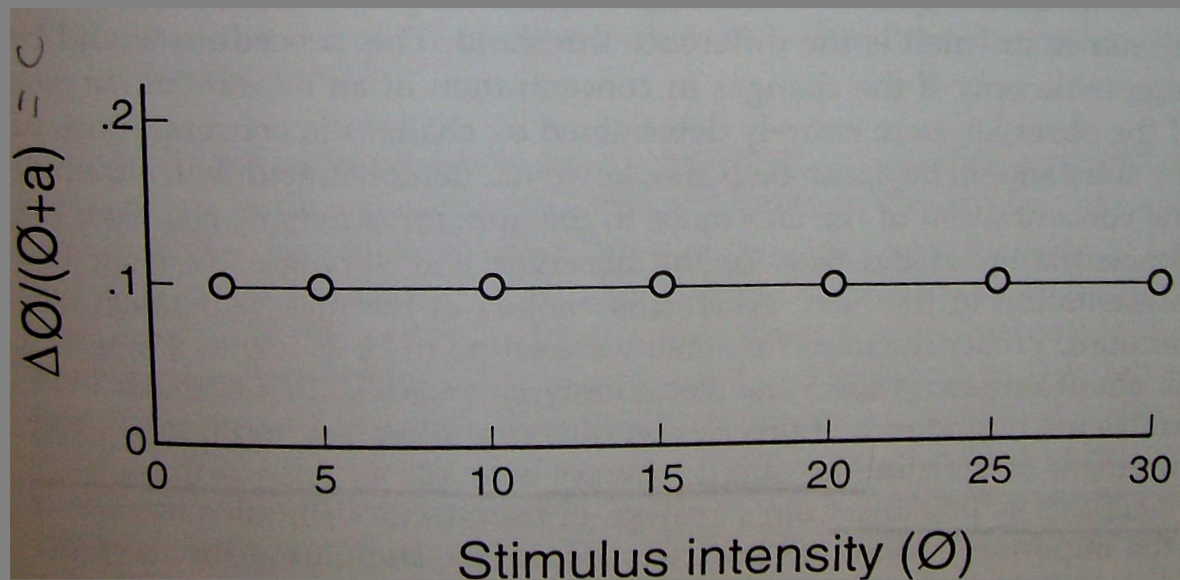
## Effect of an additive constant $a$

- All the empirical values are often the same for all values of  $\Phi$  when the correct value of  $a$  has been chosen.
- $\Delta\Phi/\Phi$  constant but not for low levels



## Effect of an additive constant a

- $\Delta\Phi/(\Phi+a)$  plotted as a fx of  $\Phi+a$  all the values of  $\Phi$  are well described by the Weber's law



# The significance of the constant

- The constant  $a$  must be related to the operation of sensory system near threshold.
- The exact significance of  $a$  has not been determined but maybe represent the amount of sensory noise that is present in the system when the value of  $\Phi$  is 0. Since sensory noise is a spontaneous activity that exist as a background to stimulus in the nervous system its level may greatly influence the value of  $\Delta\Phi$  for very low intensity value.

# Absolute vs. difference thresholds

- The interpretation of the constant “a” is that the concept of sensory noise provide a principle for understanding absolute and difference thresholds:

**ABSOLUTE THRESHOLD:** value of  $\Phi$  needed to increase the neural activity above the sensory noise level by some critical amount

**DIFFERENCE THRESHOLD:** change in  $\Phi$  needed to produce a critical difference in neural activity level associated with two intensity of stimulation

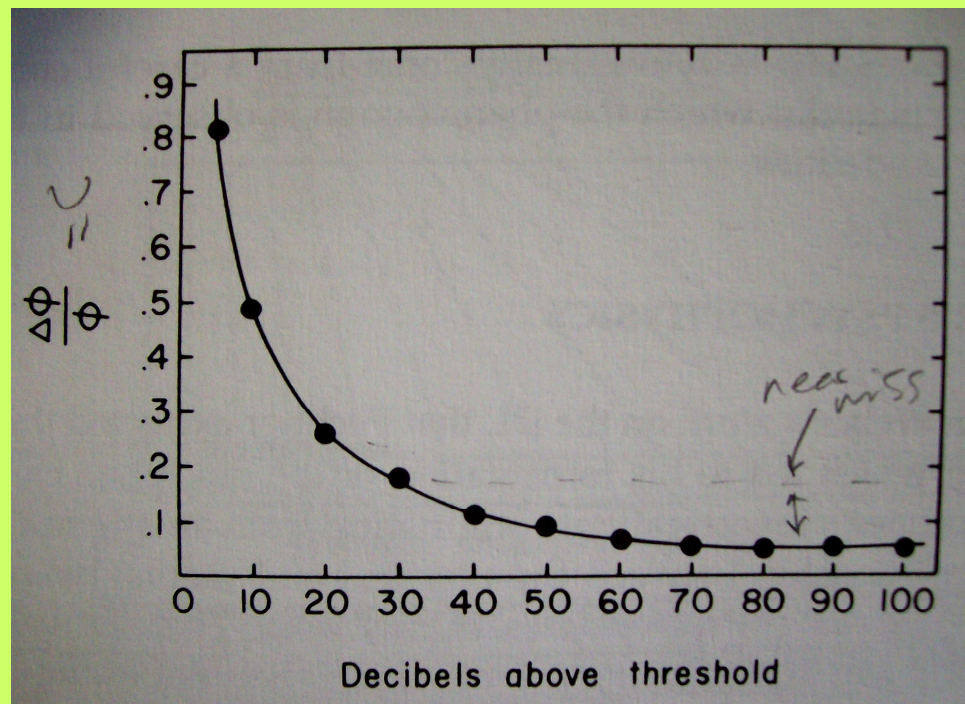
# Noise

- Both absolute and difference thresholds involve the discrimination of differences in levels of neural activity. The noise can be originated from outside as well as from inside the observer. One source of external noise is uncontrolled fluctuation in the stimulus.
- i.e. for sense of smell have illustrated a large effect that external noise can have in psychophysical experiments ( $\Delta\Phi$  = form 25-35%) while the absolute threshold is the lowest measured for any sensory modality.
- However if the noise was controlled was simple obtain a good Weber's fraction-> this illustrate the importance of precise stimulus control in psychophysics.



## One other exception to the Weber's law

- Another exception to the WL observed for discrimination for auditory and tactile vibratory discrimination is the “near miss” where  $\Delta\Phi/\Phi$  first decrease rapidly as function of  $\Phi$  but instead of becoming constant continues to decrease gradually

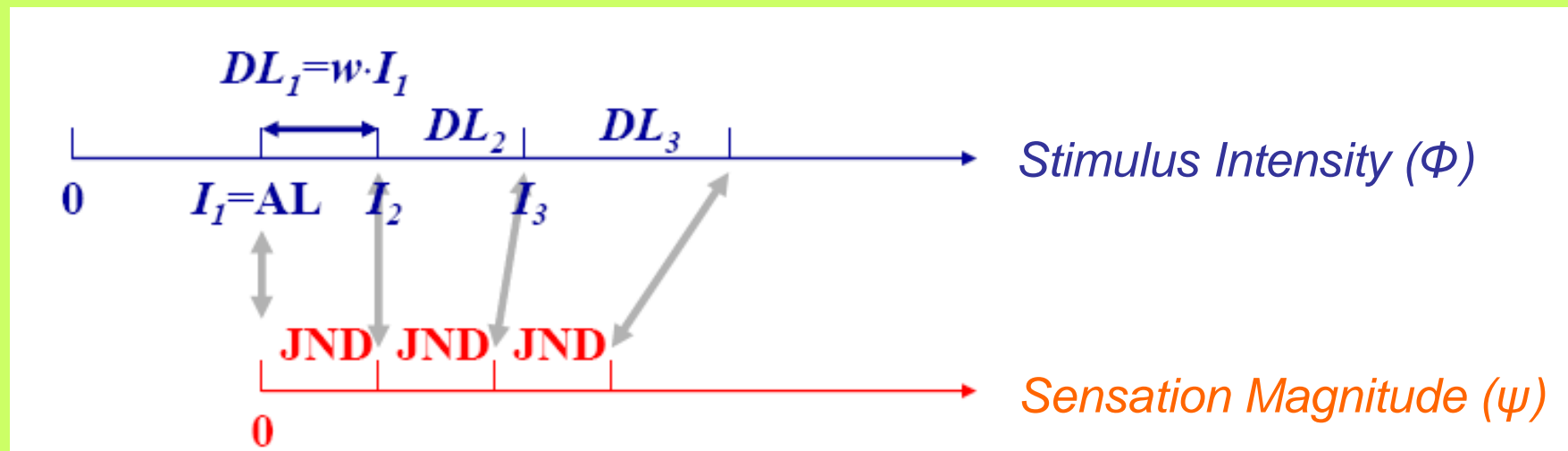


# Fechner's psychophysics

- Fechner's work originating from an interest to establish a precise relationship between the physical event and mental reaction (1860 Elements of psychophysics).
- He wanted to find a way to give to brightness loudness and painfulness (for example) a number that represent the experience.
- As the stimulus intensity increase, it takes greater and greater changes in intensity change the sensation magnitude by some constant amount.

# ***Fechner 's law***

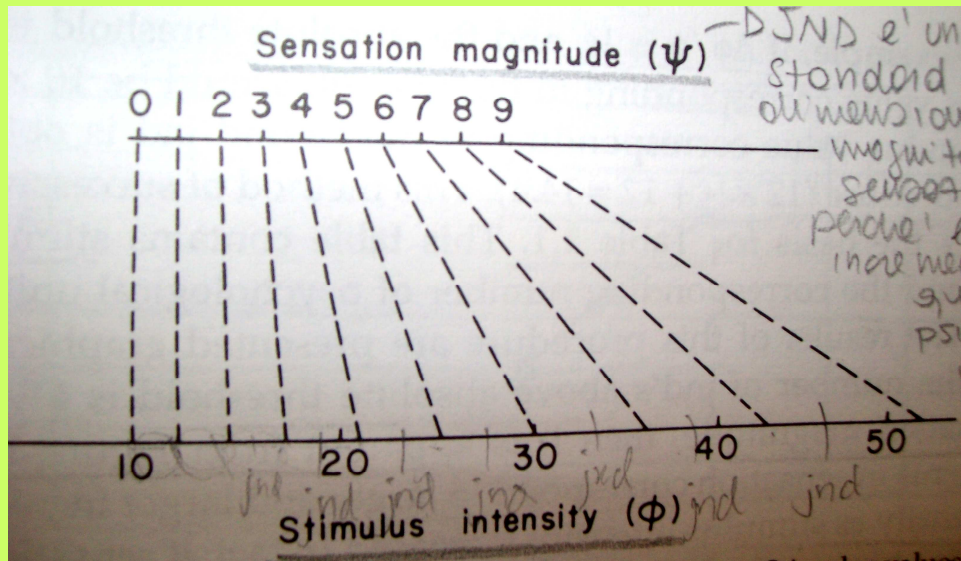
- Fechner proposed that sensation magnitude could be quantified indirectly by relating the value of  $\Delta\Phi$  on the physical scale to the corresponding values of jnd (just noticeable difference) stimulus dimension  $\Phi$  in the sensation dimension ( $\psi$ ) on the psychological scale*



# Fechner 's law

Jnd is interpreted as a standard units of sensation magnitude because it is the smallest detectable increment in a sensation and is therefore always psychologically the same size.

He develop a scale of sensation magnitude starting from the absolute threshold.



i.e. if

$$\Delta\phi / \phi = 1/5$$

Absolute Threshold=10

The first jnd=10\*1/5+10=12

The second=12\*1/5+12=14.4

By following this method you can create the stimulus intensity with the corresponding number of psychological units (number of jnd's)

# *Fechner 's law*

$$\Psi = k \log \Phi$$

- $\Psi$  = sensation magnitude
- $K$  = constant multiplier that depends on the particular sensory modality and dimension
- $\Phi$  = intensity of the stimulus in units above absolute threshold
- *Fechner derived this general equation from the Weber's law*
- *To use this law we need to do two assumption:*
  - the Weber law should be correct
  - the jnd should be an equal increment in sensation at all levels of stimulus intensity
- *However some experimental tests have shown that jnd's are not always equal-> for this reason it is not considered an accurate statement of the relationship between stimulus intensity and sensation magnitude .*