Approaches to the Study of Perception

Introduction to Psychophysics

How can we study perception?
What makes an interesting perceptual question?
• Phenomenology
• Theoretical Psychology

How can we measure perception?
• Psychophysics

How does the brain account for the perception (which areas and processes are involved)?
• Biological techniques (anatomy, neural recording, MRI, lesions)
• Computational models

Psychophysics Labs

Introduction to Visual Psychophysics

• Psychophysics is the study of the relationship between physical stimuli and the perceptual experiences they generate

• Historically, psychophysics was directed at answering philosophical questions about the relationship between mind and body.

• Modern psychophysics is mainly a set of tools for investigating the nervous system

Gustav Fechner
The founder of psychophysics

The primary contributions of Fechner:
• Was interested in solving the mind-body problem

• Wanted to establish the relationship between changes in the physical domain and changes in subjective sensation

• He developed the “classical” psychophysical methods as tools to investigate this relationship

• He formulated the first psychophysical “law”
The secondary contributions of Fechner:

• Wrote satirical treatises under the name of Dr. Mises on such topics as why angels should be spherical

• Later in life, began to write seriously on topics such as the mental life of plants!

Psychophysics is concerned with functional relationships between physical characteristics and subjective sensation.

Modern psychophysics uses these data to draw inferences about underlying physiological mechanisms.

The data are gathered using different psychophysical methods.

The Applications of Psychophysics

Although psychophysical procedures are used mostly for the measurement of sensation, they can also be applied to any situation in which an accurate assessment of subjective experience is required:

Everyday Examples

Is my hearing normal? Do I need glasses?
Which of these job candidates would make the best pilot (e.g., best visual acuity, fastest reaction times?)
How can we design the best equipment (e.g., ambulance siren, traffic lights)?

The Domains of Psychophysics

Detection

• absolute threshold: boundary between detectable and undetectable

• Example: How loud does your cell phone ring have to be for you to hear it in a quiet room?

Discrimination

• just noticeable difference (JND): minimum amount by which a stimulus must be changed to produce a noticeable difference

• Example: How different in pitch (high vs. low tones) does your cell phone have to be from your friend’s phone in order for you to tell the difference?

The Measurement of Sensation

• Let’s begin with detection

• Must assume:
  – an absolute threshold below which no sensation is present
  – An orderly relationship between stimulus intensity and sensation level

Sensory Threshold

A hypothetical threshold function with perfect discrimination
Intensity/Response Function

A realistic threshold function with imperfect discrimination

The Psychophysical Methods

- The “classical” psychophysical methods were developed by Fechner
  1) Method of adjustment
  2) Method of limits
  3) Method of constant stimuli
- Other, more sophisticated techniques have been developed more recently

The Method of Adjustment

Adjust the volume until you can just barely hear the sound

The Spinal Tap caveat:

The Method of Limits

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Threshold = mean of crossovers = 98.5

The Method of Limits

- Adjust intensity in discrete steps until observer reports that stimulus is just detectable
- Experimenter has control of stimulus
- Typically make adjustments from above and below

Advantages:
- Simple task
- Efficient
- Full observer involvement

Disadvantages:
- Subject bias
- Possibility of adaptation
- Errors of anticipation

Trial Number

Threshold = mean of crossovers = 98.5
The Method of Constant Stimuli

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Plot Graph

Method of Constant Stimuli

Plot psychometric function

4/8 = 50% point crosses function at threshold = 98.7

The Psychometric Function for Thresholds

- The psychometric function is a description of the relationship between stimulus intensity and subjective experience
- Threshold defined at some point of the function (not always 50%)
- Variability shown by scatter of data points

Psychophysical Functions

Many psychometric functions → psychophysical functions

- Sensitivity = 1/threshold
- Lowest threshold = highest sensitivity

The Method of Constant Stimuli

- Experimenter has control of stimulus
- Several stimulus values (5-9) chosen to “bracket” assumed threshold
- Stimuli presented many times in random order
- “Psychometric function” derived from proportion of ‘yes’ responses

The Method of Constant Stimuli

- Advantages:
  - Essentially eliminates observer bias
  - Reduces adaptation
  - Gives very reliable results
  - Provides additional data about observer’s performance
  - Eliminates errors of anticipation and habituation

- Disadvantages:
  - Very inefficient and time consuming
  - Needs preliminary estimate of threshold to decide on stimulus values
**Difference Thresholds**

How much do you need to change a stimulus to detect the change?

- Example: Does this block weigh more than that one?

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**Psychometric Functions for Discrimination**

It is possible to use the method of constant stimuli to measure a person’s ability to discriminate between two stimuli.

Two measurements can be derived:

- Just Noticeable Difference (JND): \( \frac{75\% \text{ point} - 25\% \text{ point}}{2} \)
- Point of Subjective Equality (PSE): 50\% point

**Psychometric Functions for Discrimination**

- The slope of function gives information about how sensitive the observer is to small changes

**Weber’s Law**

Ernst Weber:

- Size of difference threshold was proportional to the size of the standard
- Weber Fraction = \( \frac{\Delta I}{I} \)
- Example:
  - Block 1 weighs 100 g, difference noted for 103 g block, JND = 3 g
  - WF = \( \frac{3}{100} = 0.03 \)
  - Block 2 weighs 1000 g, difference noted for 1030 g block, JND = 10 g
  - WF = \( \frac{10}{1000} = 0.01 \)

Weber’s Law:

WF is constant

**Improvements on Methods**

- Faster determination of thresholds
  - staircase method

- Methods that are less susceptible to subject’s criteria
  - forced choice procedures
  - signal detection theory

**The “Staircase” Methods**

- How can we determine a threshold as quickly as possible
- The staircase methods represent a compromise between the method of limits and the method of constant stimuli

- Efficient
- Avoid observer bias
- Avoid errors of anticipation and habituation
Single Staircase Method

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Threshold = average of reversal points (usually 6 or 7) = 98.75

Limitations of the single staircase:
- Although the single staircase is efficient, the observer can bias his data by the way he responds. He can predict how the stimulus will change.
- This problem can be dealt with by using a dual staircase procedure.

Problem: The threshold depends on the observer’s criteria and willingness to guess.

Simplest solution: Method of Forced-Choice.

Forced-Choice Procedures

Two Alternative Forced Choice (2AFC)
Is the square on left or right?
- Observer must choose between two or more options, guessing if necessary
- Can also be done sequentially (two interval forced choice)
- Good for cases where observers may be less willing to guess
  - elderly people
  - blindsight patients
- Produces lower ‘thresholds’
- Shows that nervous system can register more information than one is aware of

Signal Detection Theory

The threshold depends on:
1) The observer’s real threshold
2) The observer’s criterion for report (liberal vs. conservative)

Example: Pain sensitivity

Threshold is 75% correct
Chance is 50% correct
Quick Review

Psychophysics

Threshold
Absolute Threshold
Difference Threshold
PSE
JND
Weber’s Law

Fechner’s Methods
Method of Adjustment
Method of Limits
Staircase Method
Method of Constant Stimuli

Criterion-based Methods
Forced Choice
Signal Detection Theory

The determination of ‘thresholds’ still plays a major role in contemporary psychophysical research.

Of course, researchers are aware of the problems with the different techniques and design their experiments using the best techniques.

Thought experiments:
Which method would you use (or avoid) if you wanted to obtain a threshold measurement:

a) as quickly as possible?
b) for an elderly person?
c) with information about points around the threshold?
d) to compare cross-cultural groups?
e) when adaptation was a concern?