Sensation & Perception: Research methods

Weight Perception

Large

Small

Which one is heavier?
Outline

1. What's going on in the brain?
   A. Single-cell recording
   B. Brain imaging
      i. PET
      ii. fMRI
2. Psychophysics
   A. Thresholds
      i. Absolute
      ii. Difference
   B. Psychophysical Methods (classical ways to measure thresholds)
      i. Method of Limits
      ii. Method of Adjustment
      iii. Method of Constant Stimuli
      iv. Staircase Method
      v. Method of Constant Stimuli for difference threshold
         a) Concepts: (PSE, POE, CE, JND)
   C. Psychophysical scaling
      i. Weber's Law
      ii. Fechner's Law
      iii. Stevens's Law
3. Signal Detection Theory
   A. A human "problem".
   B. The solution

![Diagram of the perceptual process]
Single-cell recording
**Brain “imaging”**

Positron Emission Tomography (PET)


- Scan while participant is looking at a flickering checkerboard pattern
- Scan while participant is looking at a blank screen

Difference image

Limitations: radioactivity, temporal resolution, spatial resolution
Brain “imaging”

Functional Magnetic Resonance Imaging (fMRI)

Measures oxygen level in blood in brain. More activity -> more oxygen needed.

Psychophysics

The study of the relationship between the physical energy in a stimulus and the perceptual experience that it produces.
Thresholds

**ABSOLUTE THRESHOLD:** The minimum intensity of stimulation required to produce a sensation (the lowest detectable intensity of a stimulus).

**DIFFERENCE THRESHOLD:** The minimum difference in intensity between two stimuli that can be detected (smallest detectable amount of change in a stimulus). This is also known as the **JUST NOTICEABLE DIFFERENCE (JND)**.
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   A. A human “problem”.
   B. The solution
Method of Limits

1. Present an *orderly series of stimulus intensities*.
2. At each presentation: Did the subject detect the stimulus?
3. **Threshold** = midpoint between intensities where the subject’s response changed.

<table>
<thead>
<tr>
<th>Physical Stimulus Intensity</th>
<th>Series #1</th>
<th>Series #2</th>
<th>Series #3</th>
<th>Series #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>51</td>
<td>Y</td>
<td></td>
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<tr>
<td>50</td>
<td>Y</td>
<td>Y</td>
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<td>49</td>
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<td>Y</td>
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<td>42</td>
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<tr>
<td><strong>Threshold</strong></td>
<td>48.5</td>
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</tbody>
</table>

Potential problem with the method #1

**Problem:** The subject tends to keep reporting that they detected the stimulus. *(Error of habituation/perseveration)*

**Solution:** Present both descending and ascending series:

<table>
<thead>
<tr>
<th>Physical Stimulus Intensity</th>
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<tr>
<td><strong>Threshold</strong></td>
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</tbody>
</table>
Potential problem with the method #2

**Problem:** The subject produces a consistent pattern of responses. They remember how many stimuli they detected (or didn’t detect) at the beginning of each type of series. (Error of anticipation)

**Solution:** Stagger the starting point of successive series:

<table>
<thead>
<tr>
<th>Physical Stimulus Intensity</th>
<th>Series #1</th>
<th>Series #2</th>
<th>Series #3</th>
<th>Series #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>51</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>50</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>49</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
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<td>48</td>
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<td>N</td>
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<td>42</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td><strong>Threshold</strong></td>
<td><strong>46.5</strong></td>
<td><strong>46.5</strong></td>
<td><strong>47.5</strong></td>
<td><strong>48.5</strong></td>
</tr>
</tbody>
</table>

These errors are examples of the sorts of difficulties that you might encounter when you are trying to measure mental phenomena. Careful experimental design can help to reduce their effects.

**Method of Adjustment**

This method is the **SAME as the method of limits** except that the subject (or the experimenter) CONTINUOUSLY ADJUSTS the stimulus.
Method of Constant Stimuli

(More accurate than method of limits. But it takes more time to establish threshold.)

How it works:

1. Use a fixed set of stimulus intensities selected in advance (there should be intensities at each extreme that are clearly above and below threshold).

2. Present stimulus intensities in a RANDOM ORDER (NOT an orderly series).

3. Present each intensity several times, each time asking the subject for a "yes/no" judgment.

Theoretically, the results would look like this:

Q: How do we determine the absolute threshold?
A: Random noise and variation in all processes involving humans.

Q: Why do the theoretical and actual results differ?
A: Random noise and variation in all processes involving humans.

This is known as the Psychophysical Function (or psychometric function).

Demo 1.3
Staircase Method

1. Begin with an intensity far below (or above) the threshold.
2. Increase the intensity one step if not detected; decrease one step if detected.
3. Stop after a predetermined number of response reversals.
4. Threshold = average intensity of the reversals.

More efficient than method of constant stimuli. Why?

DIFFERENCE THRESHOLD: The minimum difference in intensity between two stimuli that can be detected (smallest detectable amount of change in a stimulus). This is also known as the JUST NOTICEABLE DIFFERENCE (JND).
Method of Constant Stimuli for Difference Threshold

1. Use pre-selected set of stimulus intensities presented in a random order.
2. On each trial present TWO stimuli:
   One is the standard, used as a reference stimulus.
   The other is the comparison: intensity varies from trial to trial.
3. Possible responses:
   “The comparison is greater than the standard”
   or “The comparison is less than the standard”.

Point of Subjective Equality (PSE): Stimulus intensity that is judged to be greater than the standard half of the time and less than the standard half of the time.

Point of Objective Equality (POE): the actual value of the standard.

PSE does not necessarily equal POE, and the difference between them is called the Constant Error (CE).  \( \text{PSE} - \text{POE} = \text{CE} \)

Why do we get a Constant Error?

1. **Space Difference**: comparison and standard are experienced in different places.

   or

2. **Time Difference**: comparison and standard are experienced at different times.
Difference threshold (JND)

Just Noticeable Difference (JND)

This interval contains 2 JNDs. The difference threshold is one-half this interval.

% of responses "comparison is greater than the standard" 0 10 20 30 40 50 60 70 80 90 100 10 11 12 13 14 15 16 17 18 19 20 21 22
Weight of comparison stimulus (pennies)

Figure 3: Proportion of "farther" judgments as a function of relative probe position, pre
Size-Weight Illusion

How many of you thought the small one was heavier?

The larger of two equal weight objects feels lighter. (This is an example of how context can influence perception)

Another example of how context can influence perception:

Other examples of contextual influences on perception.

- More Than Meets The Tongue: Color Of A Drink Can Fool The Taste Buds Into Thinking It Is Sweeter
- Does Touch Affect Flavor? Study Finds That How A Container Feels Can Affect Taste
- Good News For Veggies: Personal Values Deceive Taste Buds
Outline

1. Single-cell recording
2. Brain imaging
   1. PET
   2. fMRI
3. Psychophysics defined
4. Thresholds
   1. Absolute
   2. Difference
5. Psychophysical Methods (classical ways to measure thresholds)
   1. Method of Limits (absolute threshold)
   2. Method of adjustment (absolute threshold)
   3. Method of Constant Stimuli
      1. Absolute threshold
      2. Difference threshold
         1. Concepts: (PSE, POE, CE, JND)
6. Psychophysical scaling
   1. Weber's Law
   2. Fechner's Law
   3. Steven's Law
7. Signal Detection Theory
   1. A human "problem".
   2. The solution

Psychophysical Scaling

Psychophysics also deals with the perceptual experience over a wide range of stimulus intensities.

Psychophysical scaling is used to describe relationships between subjective experience and stimulus intensity.
Weber’s Law

Weber conducted an experiment with weights and found that the JND was greater and greater for increasing stimulus magnitudes.

Standard = 100 g  JND = 2 g
Standard = 1000 g  JND = 20 g

So, JND = a constant proportion of the intensity of the standard.

\[ \Delta I = k \frac{I}{I} \]

Weber fraction \( k = \frac{\Delta I}{I} \)

**TABLE 1.2** Weber Fraction for Four Different Perceptual Dimensions

<table>
<thead>
<tr>
<th>Sensory Domain</th>
<th>Perceptual Dimension</th>
<th>Weber Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taste</td>
<td>Saltiness</td>
<td>.083</td>
</tr>
<tr>
<td>Vision</td>
<td>Brightness</td>
<td>.079</td>
</tr>
<tr>
<td>Audition</td>
<td>Loudness</td>
<td>.048</td>
</tr>
<tr>
<td>Touch</td>
<td>Heaviness</td>
<td>.020</td>
</tr>
</tbody>
</table>
Car sales

Do you want this for $1000?

Comfort Access system

Comfort Access system offers an even greater degree of convenience: keyless access to your car. Simply carrying the remote key in a pocket allows you to unlock the doors by touching the door handle. You can also turn the engine on or off by pressing the Start/Stop button without first inserting the remote key.

Which do you prefer: stripped down, or fully loaded?

$112,225  $113,225
Fechner’s Law

Two assumptions:

1. Weber’s law is true.
2. Each JND feels the same (the JND is the basic unit of perception).

\[ P = c \log S \]

(Perceived Magnitude) \quad (Stimulus Intensity)

Equal increments in physical intensity produce smaller and smaller increments in perceived magnitude.

Fechner’s Law 1860’s
Sprint Commercial

Sprint: “Our lines are twice as quiet as AT&T’s”

Fechner’s Law is not ideal because:
• Weber’s law is not always correct &
• There is a function that better describes the relation between physical stimulus magnitude and perception for a wide range of stimulus modalities.
To Honor Fechner and Repeal His Law

A power function, not a log function, describes the operating characteristic of a sensory system.

S. S. Stevens

One hundred years ago G. T. Fechner (1) published the fruits and findings of a ten-year labor—an event that we celebrate as the nascent of the discipline called psychophysics. In the century since the Elements der Psychophysik first made its stir, the simple but controversial logarithmic law that goes by Fechner's name has invaded almost all the textbooks that mention human understanding on how they should build it; my psychophysical edifice will stand because the workers will never agree on how to tear it down."

These words were published 17 years after the appearance of the Elements. By that time Fechner had had full opportunity to correct his magnum error, for at least two different arguments had by then been made in favor of a logarithmic function as the sole contender, so that little or nothing was heard of the power function for many decades. If a change is now setting in, it is because new techniques have made it plain that on some two dates sensory continua the subjective magnitude grows as a power function of the stimulus magnitude (9).

It is understandable that Fechner should fight stubbornly throughout his later decades to salvage his intellectual investment in the thesis that a measure of the uncertainty or variability in a sensory discrimination can be used as a unit for the scaling of the psychological continua. He had sensed the essence of this possibility as he lay abed on that famous morning of 22 October 1850, and he had put the idea promptly and tenaciously to work. But why should such an unlikely notion have persisted for so long in other circles, and why should it have blossomed out in such noted and provocative guises as those devised by Thorstone and his school? I have puzzled so often about the ability of this fancy to persist and grow famous that I have ac-


Magnitude Estimation

How it works:

1. Present standard stimulus and assign it an arbitrary number.
2. Present other stimuli and subject assigns each a number relative to the standard.

$P = j S^n$

Stevens’ Power Law

Perceived magnitude
Stimulus intensity

Try it with judgments of line lengths.
Magnitude Estimation

Can be informative about the relation between physical stimulus attributes and perceived magnitude for almost any sensory quality.

Stevens' law fits many sensory dimensions

\[ P = j S^n \]

If \( n > 1 \), as physical intensity increases, perceived sensation increases at an **increasing rate**. (Equal increments in physical magnitude produce larger and larger increments in sensation.)

If \( n = 1 \), as physical intensity increases, perceived sensation increases at a **constant rate**.

If \( n < 1 \), as physical intensity increases, perceived sensation increases at a **decreasing rate**.
**Psychophysical Scaling**

Weber’s Law  \[ \text{JND} = k S \quad (\Delta I = k I) \]

Fechner’s Law  \[ P = c \log S \]

Stevens’ Law  \[ P = j S^n \]

---

**TABLE 1.3**  
Stevens Power Law Exponent in Different Sensory Domains

<table>
<thead>
<tr>
<th>Sensory Domain</th>
<th>Perceptual Dimension</th>
<th>Exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taste</td>
<td>Sweetness</td>
<td>0.8</td>
</tr>
<tr>
<td>Vision</td>
<td>Brightness</td>
<td>0.3</td>
</tr>
<tr>
<td>Audition</td>
<td>Loudness</td>
<td>0.5</td>
</tr>
<tr>
<td>Touch</td>
<td>Warmth</td>
<td>1.6</td>
</tr>
<tr>
<td>Touch</td>
<td>Heaviness</td>
<td>1.5</td>
</tr>
<tr>
<td>Touch</td>
<td>Electric shock</td>
<td>3.5</td>
</tr>
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A “problem” with humans
People are affected by many factors that can bias their perception.
The solution:

Signal Detection Theory

Permits the measurement of a person's sensitivity (to a weak signal) in a manner that is unaffected by their biases.

Signal Detection Experiment

1. Use one fairly WEAK stimulus intensity.
2. On every trial present NOISE.
3. On some trials have a signal imbedded in the noise.
4. Subject decides:
   1. "I detected a signal" or
   2. "I did not detect a signal"

Demo 1.4
A table and diagram illustrate the outcomes of signal and noise trials based on responses: "Yes" and "No".

**Stimulus Table**

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Signal presented</th>
<th>Signal not presented</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Yes&quot;</td>
<td>HIT</td>
<td>FALSE ALARM</td>
</tr>
<tr>
<td>&quot;No&quot;</td>
<td>MISS</td>
<td>CORRECT REJECTION</td>
</tr>
</tbody>
</table>

**Hit + Miss** = 100% of the signal trials

**FA + CR** = 100% of the noise trials
Simulation:

<table>
<thead>
<tr>
<th>Signal presented</th>
<th>Signal not presented</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hit Rate</strong></td>
<td><strong>False Alarm Rate</strong></td>
</tr>
<tr>
<td>90/100</td>
<td>15/100</td>
</tr>
<tr>
<td>10/100</td>
<td>85/100</td>
</tr>
</tbody>
</table>

Hit rate = 90/100  False alarm rate = 15/100

Receiver Operating Characteristic (ROC)

False Alarm Rate (Proportion of False Alarms)

Simulation:

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Hit Rate</strong></td>
<td><strong>False Alarm Rate</strong></td>
</tr>
<tr>
<td>96/100</td>
<td>8/10</td>
</tr>
<tr>
<td>15/100</td>
<td></td>
</tr>
</tbody>
</table>

Hit rate = 96/100  False alarm rate = 8/10

Receiver Operating Characteristic (ROC)

Isosensitivity curve
Proportion of Hits

Proportion of False Alarms

Each curve is called an ISOSENSITIVITY curve.

If a person falls BELOW the diagonal, they either have the meanings of “yes” and “no” confused, or they are trying to fool you.
If we did two experiments, one with each of these payoff matrices, we'd get two different data points that were **BOTH ON THE SAME ISOSENSITIVITY CURVE**.