Psychophysics

Absolute Threshold

- Absolute threshold is defined as the smallest amount of stimulus energy necessary for an observer to detect the stimulus.
- The idea of an absolute threshold dates back to the early 1800s, when the German philosopher J. F. Herbart suggested that for a mental event to be experienced it had to be stronger than some critical amount.
  - This idea, which was developed further by Gustav Fechner in his book *Element of Psychophysics* (1860) and others after him, forms the basis of what has come to be called classical threshold theory.

According to classical threshold theory there is a sharp step between an intensity at which an observer can’t detect a stimulus and the intensity at which an observer can detect a stimulus.

Measuring Threshold

- Psychophysical methods are one of the earliest methods used in the study of sensory psychology.
- The early psychophysicists were interested in measuring thresholds.
- More recently we have begun to develop methods of measuring subjective magnitude above threshold.
- One threshold that the early psychophysicists were interested in measuring was absolute threshold.

The basic idea underlying this theory is that at the absolute threshold there is a sharp transition between a state in which an observer cannot detect the stimulus and in which the observer can detect the stimulus.

- If the intensity is below the threshold
- If the intensity is above the threshold

According to this idea, an observer will never be able to detect a stimulus with an intensity of 10, 11, or just under 12.
- Will always be able to detect a stimulus with an intensity of 12 or greater.
- The absolute threshold would therefore be 12 in this case.
One way to think about classical threshold theory is to relate the threshold to activities in the nervous system. We know that there is always a level of nerve activity, called spontaneous activity, that exists even in the absence of any situation. It would follow from classical threshold theory that we can detect a stimulus when its presentation causes some critical change in neural activity from the spontaneous level. This may be an increase in neural activity or may be a decrease in neural activity. Results such as those plotted in the earlier graph rarely occur. A more usual result is shown in the next graph.

The transition between not detecting the stimulus and detecting it is usually gradual rather than abrupt. Transition between nondetection and detection occurs only if all factors remain constant during the experiment. But in reality everything is not constant.

For example:
- Level of spontaneous activity in the nervous system
- Sensitivity of receptors that pick up the stimulus
- Attention of the observer vary with time
- These variations cause slight shifts in the threshold
- So that the threshold is different at different points in time.
- These variations cause the abrupt transition to become the gradual transition.

In Elements of Psychophysics, Fechner described three methods of determining thresholds.
- Method of constant stimuli
- Method of limits
- Method of adjustment

Methods of Constant Stimuli
- To determine a threshold using the methods of constant stimuli:
  - First it is necessary to pick the stimuli to be presented to the observer.
  - Usually five to nine stimuli are used.
  - The most intense being clearly above the threshold so that the observer detects it without fail.
  - The least intense being clearly below the threshold so that the observer can never detect it.
  - The stimuli between these two are of intermediate intensity so that they are detected on some presentation and not on others.
  - Each stimulus is presented a number of times in random order.

Example
- Each of the six light intensities is presented ten times in random order.
- The percentage of times that each light is detected is plotted on the vertical axis.
- The results:
  - Light with intensity of 150 is never detected.
  - Light with intensity of 200 is always detected.
  - Lights with intensities in between are sometimes detected and some times not detected.
  - The threshold is usually taken as the intensity that results in detection in 50% of the trials.
  - In this example the threshold is an intensity of 180.
Methods of Limits

- This method is similar to the method of constant stimuli since the experimenter presents different stimuli.
- And ask the observer to indicate whether he or she can detect the stimulus.
- The major difference between the two methods is:
  - Method of constant stimuli the stimuli are presented in random order.
  - Method of limits the stimuli are presented in ascending or descending order.
- An example of the Methods of limits L

Method of Limits

- On the first series of trials, the experimenter presents a light above threshold and the observer indicates by a "yes" response that the light is seen.
- This response is indicated by a “Y” at an intensity of 105 on the table.
- The experimenter then decreases the intensity and the observer makes another judgement.
- This continues until, at an intensity of 98, the observer indicates by an answer of "no".

A Note of Caution

- You should always run both ascending and descending trials.
- This will avoid response biases.
- Subjects may continue giving the same response after the threshold.

Method of Adjustment

- In this method, the intensity of the stimulus is slowly changed by either the observer or the experimenter until the observer says that he or she can just barely detect the stimulus.
- This just barely detectable intensity is then taken as the absolute threshold.
- When the observer adjusts the stimuli, this method has the advantage of giving the observer an active role in the proceedings.
- It also maximizes the probability that he or she will stay awake during the entire experiment!
- Which of these methods is usually used to measure threshold?
- The answer depends on both the accuracy that is need and the amount of time available.

- The method of constant stimuli is the most accurate method but takes the longest time.
- The method of adjustment is the least accurate but is the fastest.
**Difference Threshold**

- When measuring the absolute threshold we are interested in determining the minimum amount of stimulus energy that can be detected.
- When measuring the **difference threshold** we are interested in determining the minimum difference between two stimuli that can be detected.

**Ernst Heinrich Weber**

- The pioneer in the study of difference threshold was Ernst Heinrich Weber.
- Who, in 1834, published the results of experiments in which he asked observers to lift a standard weight and a comparison weight and then judge which was heavier.

- By having observers compare a large number of different weights, Weber was able to determine the **difference threshold**.
- He found that the smallest difference two weights that could be reliably detected.
- He found that the size of the difference threshold, or **just noticeable difference** (JND) depends on the weight of the stimulus.
  - For example, an observer can just notice the difference between a 100-gram stimulus weight and 103 gram comparison weight.
  - The JND in this case is 3 grams.
  - If, however, the weight of the standard is increased to 1,000 grams.
  - The JND increases to 30 grams.
  - Therefore, the comparison must be increased to 1,030 before the observer can distinguish it from the standard.

**Weber’s Law**

- Weber found that the size of the JND follows a simple rule.
  - The size of the JND is a constant fraction of the size of the stimulus.
  - Expressed mathematically
    \[ JND = KS \]
    - Where K is a constant called **Weber’s fraction**.
    - S is the value of the standard stimulus.
  - This equation is usually expressed in the form
    \[ K = JND / S \]
  - Applying this equation to our example of lifted weights.
    - We find that for 100-grams standard, \[ K = 3 / 100 = 0.03 \]
    - For the 1,000-gram standard, \[ K = 30 / 1000 = 0.03 \]
    - In this example, Weber’s fraction (K) is constant.

- Does Weber’s fraction remain constant in actual experiments?
- Numerous investigators have tested Weber’s Law and found that it is true for most senses.
- As long as the stimulus intensity is not too close to the threshold.

- Weber’s fraction for lifted weights is fairly constant for two different observers.
- As long as the weight of the standard is greater than about 50 grams.
So far we have been focusing on stimuli of such low intensity that they were difficult to distinguish from the background noise or from other similar stimuli. The vast majority of our experience takes place above threshold, when we can easily hear someone talking to us or can easily see what’s around us.

Thus, it is important to ask what the relationship is between above-threshold stimuli and our perception of the stimulus. Specifically, we will ask what the relationship is between the intensity of stimulus and our perception of the magnitude of the stimulus. If we double the intensity of a light, does it look twice as bright? If we double the intensity of a tone, does it sound twice as loud?

There are two ways of answering this question, one proposed by Gustav Fechner and the other by S. S. Stevens.

Gustav Fechner (1860)

Gustav Fechner derived a relationship between stimulus intensity and perceived magnitude by making two assumptions:
- One, Weber’s law, that the JND is a constant fraction of the stimulus intensity, is valid.
- Two, the JND is the basic unit of perceived magnitude, so that one JND is perceptually equal to another JND.

It follows from these assumptions that the perceived magnitude of a stimulus can be determined by starting at the threshold and adding up JNDS.
- Thus, a light with an intensity of 20 JNDS above threshold should appear twice as bright as a light with an intensity of 10 JNDS above threshold.

Based on his two assumptions, Fechner was able to derive the following mathematical relationship between perceived magnitude and stimulus intensity:
- \[ P = K \log I \]
  - \( P \) Perceived magnitude
  - \( K \) a constant
  - \( \log \) The logarithm of the physical intensity of the stimulus

From this equation, which is called Fechner’s Law, we can determine whether doubling the intensity of light makes it appear twice as bright.

Fechner’s Law

An Example

If we set \( K = 1 \) and \( I = 10 \)
- Then \( P = 1.0 \) since the log of 10 equals 1.0
- If we double the intensity \( I = 20 \)
- Then \( P = 1.3 \) since the log of 20 equals 1.3
- Thus, according to Fechner’s law, doubling the light’s intensity does not double its brightness.
- To double the brightness of the light, we would have to increase the intensity 10 fold.
- \( I = 10 \times 10 = 100 \)
- Then \( P = 2.0 \) since the log of 100 equals 2.0.
Fechner’s law, however, has been questioned for three reasons:

1. First, the law is based on the assumption that Weber’s law is correct. As we have seen Weber’s law is correct at medium and high stimulus intensity.

2. Second, Fechner’s law is based on the assumption that the JND is the basic unit of measurement. An intensity that is 20 JNDs above threshold should therefore result in a perceived magnitude twice that as an intensity of 10 JNDs above threshold.

3. Third, Stevens (1957) proposed an alternative equation that describes the relationship between sensation and stimulus intensity for a wide range of senses more accurately than Fechner’s law.

Steven’s equation grew from a technique, which he developed, called magnitude estimation. This technique is very simple:

- The experimenter first presents a “standard” stimulus to the observer, say a light of moderate intensity.
- The experimenter then assigns a value to this light, maybe the value of 10.
- Then the experimenter presents lights of different intensities and the observer is asked to assign a number to each of these lights which is proportional to the brightness of the standard light.
- If the light is twice as bright as the standard, it gets a value of 20.
- If the light is half as bright a 5 an so on.

Thus, each light intensity has a brightness assigned to it by the observer.

Example

This graph plots the means of the magnitude estimates of the brightness of a light for a number of observer versus the intensity.

You can see from the graph that doubling the intensity does not double the perceived brightness. Doubling the intensity causes only a small change in perceived brightness, particularly at high intensity. This result is called response compression.

Another Example

As intensity is increased, the response increase, but not as rapidly as the intensity.
To double the brightness it is necessary to multiply the intensity by about nine.

Magnitude estimation for brightness, length of a line, and electric shock to the finger.
There are three different kinds of curves.
1) curves that bend down, such as the one for brightness
2) curves that bend up, such as the one for electric shock
3) straight lines, such as the one for estimating line length.

Curves that bend down show **response compression**
- Doubling the light intensity causes less than doubling of brightness.

Curves that bend up show **response expansion**
- Doubling the strength of a shock causes more than a doubling of the sensation of being shocked.

Straight lines are linear with a slope close to one
- The magnitude of the response almost exactly matches increase in the stimulus.
- Doubling the line length doubles the observer’s estimate of the length of the line.

Should we conclude from the differences in the curves that the relationship between the intensity of a stimulus and our perception of its magnitude follows different rules for each sense?

The answer to this question is that even though the curves look different, we can, in fact, find a common rule for all senses.

To find a common rule that can describe all the different curves, we have to replot the curves by plotting the
- *Logarithm of the magnitude estimates* versus
- *The logarithm of the stimulus intensity*

When we do this, all three curves become straight lines.

Functions that are straight lines on such a log-log plot are called **power functions**
- And are described by the equation \( P = KS^n \)

(P) Perceived magnitude =
(K) a constant X
(S) stimulus intensity raised to a
Power of (n)
- This relationship is called **Stevens’ power law**.

The power n, the exponent of the power law, indicates the slope of the lines in the graph.

Remembering the three types of curves,
- we can see that the slope of the curve that showed **response compression** is less than 1.0
- The slope of the linear curve is about 1.0
- The curve that shows **response expansion** is greater than 1.0.
Thus, the relationship between response magnitude and stimulus intensity is described by a power law for all senses.

- The exponent of the power law indicates whether doubling the stimulus intensity causes more or less than a doubling of the response.

What do these exponents mean in terms of our experience?

- Brightness, for example, we can be exposed to intensity ranges of 1 to 1,000 or more on a bright sunny day.
- It makes sense that our perception of brightness should not span the same range.
- If it did, we should probably be faced with a scene of such high contrast and bright glare that looking at the scene would be difficult.

Estimating line lengths is something most people have had some experience with and most people are fairly good at it.

- The exponent of 3.5 for shock seems compatible with our need to avoid potentially damaging stimuli.
- The rapid increase in pain for small increases in shock intensity serves to warn us of impending danger.
- We therefore tend to withdraw even from weak stimuli.