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Weber-Fechner Law

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Abstract
Several models have been proposed in the field of psychophysics to quantify relationships between any stimulus (e.g., touch, sound, light, and smell) and the perceived response by individuals. One such model is referred to as the Weber-Fechner Law. The Weber –Fechner Law, however, is not one law, but two separate laws: Weber's Law and Fechner's Law. Moreover, not all human senses respond to stimuli according to Fechner's law (in fact many do not). Weber's Law and special cases such as Fechner's Law are each based on the “just noticeable difference threshold” concept.

Disciplines
Agricultural Science | Agriculture | Plant Pathology

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Several models have been proposed in the field of psychophysics to quantify relationships between any stimulus (e.g., touch, sound, light, and smell) and the perceived response by individuals. One such model is referred to as the Weber-Fechner Law. The Weber −Fechner Law, however, is not one law, but two separate laws: Weber's Law and Fechner's Law. Moreover, not all human senses respond to stimuli according to Fechner's law (in fact many do not). Weber's Law and special cases such as Fechner's Law are each based on the “just noticeable difference threshold” concept.

The Difference Threshold or Just Noticeable Difference

When quantifying a difference threshold, the reason for doing so is to determine the minimum difference between two stimuli that can be detected. Researchers in the field of classical psychophysics pose the question this way: What is the just noticeable difference (JND) required to perceive that a comparison stimulus is different from a standard (or reference) stimulus?

Weber's Law

Ernest Heinrich Weber was an early pioneer in the field of psychophysics, and it was Weber who developed the concept of the difference threshold or just noticeable difference. Weber published the results of experiments in which he asked observers first to lift a standard weight and then a comparison weight and judge whether the comparison weight was greater than, equal to, or less than the standard weight. By having observers compare a large number of different standard and comparison weights, Weber was able to determine the smallest difference between two weights that could be detected reliably (i.e., the difference threshold). He found that the difference threshold or just noticeable difference was dependent on the weight of the standard (reference) stimulus. For example, if an observer can just notice the difference between a 100 g standard weight and a 103 g comparison weight, the JND in this example would be 3 g. Weber found, however, that if the weight of the standard was increased to 1,000 g, the JND was no longer 3 g but had increased to 30 g (i.e., the comparison weight must be heavier than 1,030 g to perceive a just noticeable difference). Weber investigated further and found that the size of the JND for most human senses (e.g., sight, sound, taste, and touch) is a constant fraction of the size of the standard stimulus. Expressed mathematically, this is known as Weber's Law:

$$\text{JND} = kS,$$

where *k* is a constant called the Weber fraction and S is the value of the standard stimulus. This equation is usually expressed in the form

$$k = \text{JND}/S.$$

Fechner's Law

Gustav Fechner derived a relationship between the intensity of a specific stimulus and the perceived (estimated) magnitude. To derive this relationship, Fechner made two important assumptions:

1. that the JND is a constant fraction of the stimulus (i.e., Weber's Law holds), and

2. that the JND is the basic unit of perceived magnitude, so that one JND is perceptually equal to another JND.

By accepting these assumptions, Fechner hypothesized that the magnitude of a stimulus can be determined by starting at the detection threshold (JND) and then adding JNDs. From this, Fechner derived the following mathematical relationship between perceived magnitude (P) and stimulus intensity (I):

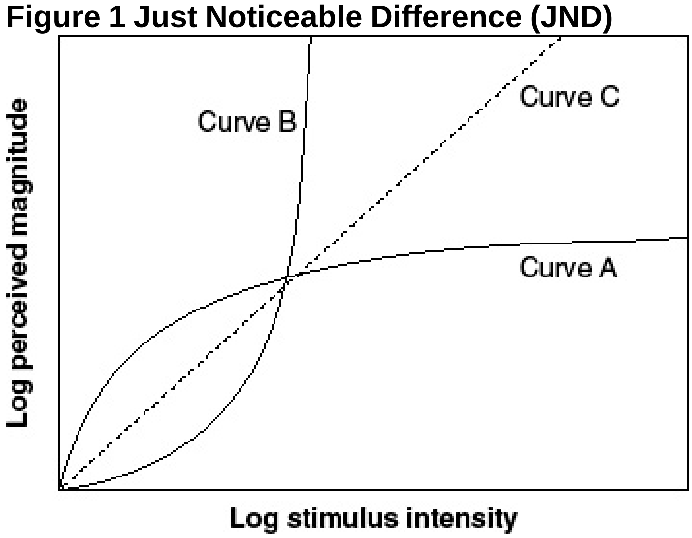
$$P = k \log I,$$

where *k* is a constant fraction (Weber's Law). Using Fechner's Law, it can be determined whether doubling the intensity of a light makes it appear twice as bright. For example, a light that is 10 JND units above the detection threshold should be perceived as being twice as bright as a light with an intensity of 5 JND units above the detection threshold. If we set *k* = 1 and I = 10, then P = 1.0 because the log of 10 = 1.0. However, if the intensity of light is doubled to 20, then P = 1.3 (not 2.0). Thus, doubling the light's intensity does not double the perceived magnitude of brightness. The second assumption of the two made by Fechner has since been questioned by those working in the field of psychophysics, and Fechner's Law (a special case) has largely been replaced by Stevens's Power Law.

Stevens's Power Law

Stanley Smith Stevens proposed that the perceived magnitude of a stimulus (*P*) equals a constant (*k*) times the stimulus intensity (*S*), raised to a power (*n*). Stevens found that for all senses (in general), the relationship between any stimulus intensity (*X*) and estimated response magnitude (*Y*) is best described by a power law, and the exponent of the power law indicates whether a doubling of the stimulus results in a doubling in the perceived stimulus (i.e., linear) or whether a doubling of the stimulus causes *more or less* than a doubling of the perceived response. Stevens's Law was found to better quantify the stimulus-response curves for a number of sensory phenomena, such as loudness, brightness, smell, taste, vibration, line length, and electric shock. Stevens's Power Law can be demonstrated by plotting the logarithm of the intensity of the stimulus (*X*) versus the logarithm of the perceived (i.e., estimated) magnitude of the stimulus (*Y*).

Figure 1 Just Noticeable Difference (JND)



Source: Nutter, F. W., Jr., & Esker, P. D. (2006). The role of psychophysics in phytopathology: The Weber-Fechner Law revisited. *European Journal of Plant Pathology* 114, 199 −213.

Note: Curves showing the relationship between perceived magnitude (Y) and stimulus intensity (X) for curve A (brightness), curve B (electric shock), and curve C (line length), adapted from Goldstein (1989).

Stevens described three types of stimulus-response curves (Figure 1). The first is called a response compression curve because the stimulus-response curve bends downward (curve A, Figure 1). For example, Stevens found that doubling light intensity (*X*) resulted in only a small change in perceived brightness (*Y*) because the exponent (*n*) was < 1.0. Thus, as light intensity increases, the perceived response also increases but not as rapidly as the intensity.

A second type of stimulus-response curve includes those that bend upward, thereby exhibiting response expansion. For example, when electric shock is applied to the finger (curve B, Figure 1), the exponent (*n*) of this stimulus-response curve was 3.5 times higher (i.e., much higher than 1.0). This indicates that a doubling of the intensity of the shock would result in more than a doubling of the sensation of being shocked. In another example of response expansion, Stevens showed that sound 20 JND units above a threshold is perceived as being much more than twice as loud as sound that is 10 JND units above threshold.

The third type of stimulus-response curve is linear or approaches linearity (i.e., the power of the exponent, *n*, is 1.0 or close to 1.0). Observers who estimated the lengths of straight lines (*Y*) in response to being shown different line lengths (*X*) were found to produce linear stimulus-response curves (see curve C, Figure 1).

- stimuli
- psychophysics
- power laws
- electric shock
- weight
- law
- shock

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See also

- “On the Theory of Scales of Measurement”

Further Readings
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