Oncothermia Journal 17:68-73 (2016)

Notes on psychophysics

Gyula Vincze*, Andras Szasz*

* Department of Biotechnics, St. Istvan University, Hungary

Published: Journal of Advances in Biology 9(1):1756-1760 (2016)

ISSN: 2191-6438
Cite this article as: Vincze Gy, Szasz A (2016) Notes on psychophysics. *Oncothermia Journal* 17:68-73

ISSN 2347-6893
Volume 9 Number 1
Journal of Advances in Biology

Notes on psychophysics

Gyula Vincze, Andras Szasz
Department of Biotechnics, St. Istvan University, Hungary
biotech@gek.szie.hu

ABSTRACT

We describe the Norwich-Wong generalization of the Weber-Fechner law in the framework of a complex, self-controlling, self-similar feedback mechanism to ensure the condition of “dendritic democracy”.

Indexing terms/Keywords

Sensing; Norwich-Wong law; Weber-Fechner law; Stevens’ power law; dendritic democracy; self-similar feedback

INTRODUCTION

We are non-detachable parts of our own environment. The world around us acts on us, acts on our sensory organs via stimulation of physical parameters according to the theorem of psychological parallelism [1], which has recently been established as a completely new science, the quantum consciousness [2].

Environmental stimuli induce reactions (sensing) in the nervous system, which “processes” and derives a reaction (answer) to environmental stimuli. Our aim is to study the physiology of the stimulus-sensing process, because the sensing-reaction phenomenon is more related to psychology.

METHOD

A definite connection between a stimulus and its sensing must be active in order to orient an individual in the outside world. This means that the same stimulus induces roughly identical sensing in different healthy individuals. However, it is clear that various individuals differ widely with respect to the intensity and richness of sensing. (by “richness”, we mean the degree of interconnectedness of sensing with a variety of other processes in the complex biosystem). In a more precise form, we describe the process as follows: a given stimulus induces *a* and *b* sensing in **A** and **B** individuals, respectively. We learn from our real experience, that *a* and *b* are not independent; they are related, which we denote by ≈, as in

$$a \approx b \qquad (1)$$

According to experience, this relation satisfies the following conditions:

$$\begin{aligned} &a \approx a, \qquad (2) \\ &\text{if } \ a \approx b, \text{than } b \approx a, \\ &\text{if } \ a \approx b \text{ and } b \approx c, \text{then } a \approx c \end{aligned}$$

where *a, b* and *c* are the sensing of arbitrarily chosen individuals **A, B** and **C**, exposed to identical stimuli. We define these relations in (2) as equivalence relations [3]. (The three relations in (2**Error! Bookmark not defined.**) are, in order, reflexivity, symmetry and transitivity.) Sensing, even in its complex conditions has equivalence relations [4]. The large set of sensing is divided into classes by equivalent relations. These classes are disjunct (they do not overlap). The same class is formed by the senses that belong to the same intensity stimulus measured in the same energy units.

For ordering decisions to be made, the relation between various senses has to be defined, by deciding which senses are larger or smaller than the others. Handling the senses as measureable physical quantities, two characters have to be fixed [5]: the zero-point and the scaling. The first fixes the reference; the last shows how the value of the sense depends on the intensity of the stimulus.

An important fact is that sensing has a threshold intensity of stimuli, below which no sensing exists. This means that when the stimulus is repeated at various intensities, then sensing will depend on the intensity, and will have an intensity-dependent repetition frequency. The threshold is individual. The upper limit of null sensing (average threshold) is fixed in a conventional way: the threshold is reached when 50% of individuals detect the stimulus.

Scaling is connected to the well-known Weber-Fechner law [6], which was discovered empirically and describes the connection between the stimulus and sensing. An attempt was made to derive this relation on a physical basis [7]. Its simplest form is:

$$S = k \ln I \qquad (3)$$

where S is sensing, I is the intensity of the stimulus and k is a constant. Note that it is the unifying equation of Weber and Fechner's discoveries. The Fechner law is more similar to the final common Weber-Fechner law, while the Weber law is its differential-form [8]. Considering the threshold intensity, we get:

$$S = k \ln \frac{I}{I_{tres}} \tag{4}$$

Furthermore, when we take into account that below the threshold, no sensing exists, then:

$$S = \begin{cases} k \ln \dfrac{I}{I_{tres}}, ha\ I \geq I_{tres} \\ 0, ha \quad I \leq I_{tres} \end{cases} \tag{5}$$

These empirical laws are revised in different aspects [9], and it is shown that in the range of small intensities, the power law (named Stevens' law) describes the phenomenon better [10]:

$$S = KI^n \tag{6}$$

Note that only the form of Stevens' law is universal, because the K and n change with the type of sensing [11].

Numerous attempts have been made to generalize the Weber-Fechner law, unifying the classical form with Stevens' law over low-intensity intervals, where unification is also applied [12]. One useful empirical generalization [12] has the form,

$$S = \frac{1}{2} k \ln\left(1 + \gamma I^n\right) \tag{7}$$

where γ and n are further constants. This becomes the classical Weber-Fechner law when $\gamma I^n >> 1$:

$$S = \frac{1}{2} kn \ln I \tag{8}$$

However, when $\gamma I^n << 1$, we get Stevens' law from the first two terms of the Taylor series of the logarithmic function:

$$S = \frac{1}{2} kI^n \tag{9}$$

Introducing the sensing threshold, the Norwich-Wong-law in (7) has the form of Stevens' law:

$$S = \begin{cases} \dfrac{1}{2} k \ln\left(\dfrac{1 + \gamma\left(\dfrac{I}{I_{tres}}\right)^n}{1 + \gamma} \right), \quad when \quad I \geq I_{tres} \\ 0, \quad when \quad I \leq I_{tres} \end{cases} \tag{10}$$

Starting from the basic assumptions of Stevens' power law, and assuming that the network of electrical and chemical connections between the cells formed by gap junctions result in a logarithmic function [13], Stevens' law can be applied. In the case of large intensities, the couplings are saturated and the law no longer holds true; however, where the intensities are small, the law is valid in its natural form.

Discussion

The Horowitz-Wong empirical law has in its argument the sum of a power law and a linear function, thus it is not identical in principle to the theory of Stevens' power law. Let us study how the two empirical laws (Weber-Fechner and Horowitz-Wong), are connected, starting with the study of sensory neurons. Such a neuron is multipolar: it has input and output signal capabilities (see Figure 11.).

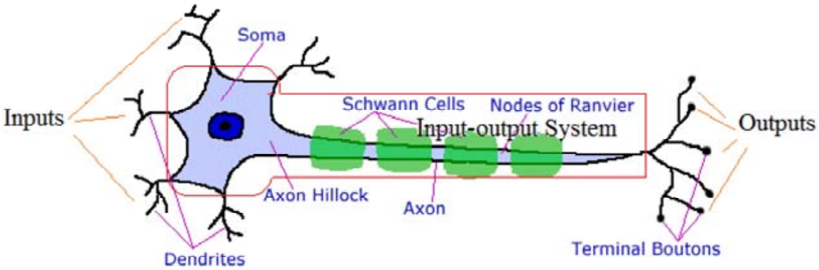


Figure 11. The sensory neuron is a system having multiple input and outputs

Most connections are made at synapses, which are the units of electrochemical signal transformation. This means that the electrical signal is transferred to a chemical transporter, upon passage through which the electric signal again forms by way of electro-chemical changes. This complex transformation causes a signal to form and be amplified, which could be important for so-called "dendritic democracy" [14].

The lengths of dendrites vary widely. The dendrite is a dissipative conductor, where the amplitude of the signal decreases during transport, but its form also changes due to dispersion during transfer. If synaptic electric-chemical-electric transformation were not there, then signals arriving from a long distance would have a smaller amplitude than those originating nearby. In this case, the terminals would have no "signal democracy" in sensing; the signals would be characteristically stronger when their path was shorter. However, experiments show a different picture: "sensing democracy" is active; synaptic transformation generates signals of equal amplitude, irrespective of signal origin, thus the signal's level at the soma will always be equal [14]. The important consequence is that when a stimulus signal reaches the synapse, an additional internal signal is combined with the original. The sum total is a signal completed by internal addition to achieve sensing democracy.

Let us consider this mixed internal-external stimulus, incorporate these into the Weber-Fechner law, and substitute the intensity with the I external and I_b internal signal:

$$S = k \ln I_{result} = k \ln(I + I_b) \qquad (11)$$

When no external signal is present, then no sensing can occur, so the equation must be modified:

$$S = k \ln(I + I_b) - k \ln I_b \qquad (12)$$

Hence:

$$S = k \ln(\frac{I + I_b}{I_b}) = k \ln(1 + \frac{I}{I_b}) \qquad (13)$$

Biological systems are self-organized [15], for which the main condition is self-similarity [16]. We assume that negative feedback control of "dendritic democracy" acts in a self-similar way, as is generally the case in bio-systems [17]. When the internal signal has power-law function-dependence on external stimuli (self-similar approach), then:

$$I_b = \gamma^{-1} I^m \qquad (14)$$

Putting (14) into (13), we reproduced the Norwich-Wong empirical equation.

$$S = k \ln(\frac{I + I_b}{I_b}) = k \ln(1 + \frac{I}{I_b}) = k \ln\left(1 + \gamma I^n\right), \qquad (15)$$

$$n = 1 - m$$

The result is very similar to that which was based on different assumptions, using neither dendritic democracy nor the power-law character [18].

CONCLUSION

The Norwich-Wong generalization of the Weber-Fechner law is valid when the internal signal (feedback control) is a self-similar function of the stimulus. In this case, the low-intensity limit gives back the well-known Stevens' power law.

REFERENCES

---

[1] Heidelberger M. (2003) The mind-body problem in the origin of logical empiricism: Hebert Feigl and psychophysical parallelism, To appear in a volume edited by Paolo Parrini and Wesley Salmon: Logical Empiricism: Historical and Contemporary Perspectives, Pittsburgh University Press

[2] Penrose R, Hameroff S. (2011) Neuroscience, quantum space-time geometry and orch or theory, Journal of Cosmology, Vol. 14. 1-29

[3] Equivalence relation -- Britannica Online Encyclopedia, (http://www.britannica.com/topic/equivalence-relation), accessed: Aug. 14. 2015

[4] Sidman M, Florida S. (2009) Equivalence Relations and Behavior: An introductory tutorial, The analysis of verbal behavior, 25, 5-17

[5] Carnap R. (1947) On the application of inductive logic, Philosophy and phenomenological research, Vol. 8, No. 1, 133-148

[6] Norwich KH. (2003) Information, Sensation and Perception, chapter 3: The empirical laws of sensation and perception, Internet by Biopsychology.org

[7] Cope FW. (1976) Derivation of the weber-Fechner law and the Loewenstein equation as the steady-state response of an elovich solid state biological system, Bulletin of Mathematical Biology, Vol. 38

[8] Weber's Law and Fechner's Law, http://www.cns.nyu.edu/~msl/courses/0044/handouts/Weber.pdf

[9] Nutter FW, Esker PD. (2006) The role of phsyhophysics in phytopathology: The Weber-Fechner law revisited, European J Plant Pathology, 114:199-213

[10] Zwislocki JJ. (2009) Sensory Neuroscience: Four laws of psychophysics, chapter: Stevens' power law; Springer-Verlag US

[11] Stevens SS. (1975) Psychophysics: Introduction to its perceptual, neural and social prospects, ed. Stevens G., Wiley, New York

[12] Norwich KH, Wong W. (1997) Unification of psychophysical phenomena: The complete form of Fechner's law, Perception and Psychophysics, 59(6), 929-940

[13] Copelli M, Roque AC, Oliveira RF, Kinouchi O. (2002) Physics of psychophysics: Stevens and Weber-Fechner laws are transfer functions of excitable media, Phys Rev E 65, 060901(R)

[14] Häusser M. (2001) Synaptic function: Dendritic democracy. Current Biology, 11:R10–R12

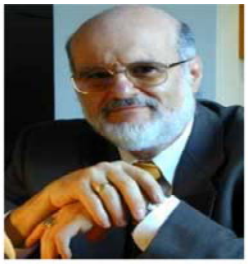
[15] Walleczek J. (2000) Self-organized biological dynamics and nonlinear control, Cambridge University Press

[16] Turcotte DL, Rundle JB. (2002) Self-organized complexity in the physical, biological, and social sciences, Proc Natl Acad Sci USA, 99(Suppl 1): 2463-2465

[17] Camazine S, Deneubourg J-L, Franks NR, et.al. (2003) Self-Organization in biological systems, Princeton University Press

[18] Nicolas S, Murray DJ, Farahmand B. (1997) The psychophysics of J-R-L Delboeuf (1831-1896), Perception, 26(10):1297-315

Author' biography with Photo



Curriculum Vitae **Andras SZASZ**

PERSONAL

1947. November 04.	Born in Budapest, Hungary

STUDIES

1967-72	Studies at Eötvös University (Physics) [MS graduation, thesis: Positron annihilation]
1974	Doctor's degree at Eötvös University (Physics)
1983	Candidate of Mathematical and Physical Sciences of Russian Academy of Sciences, (Surface physics)
1983	Candidate of Physical Sciences of Hungarian Academy of Sciences (Physics)
1996	Habilitation at St. Istvan University (Hungary) (Biophysics)

ACADEMIC APPOINTMENTS

1972-1974:	Assistant professor in Eotvos University Budapest, Hungary
1974-1982:	Associate professor in Eotvos University Budapest, Hungary
1982-1985:	Head of Metalab and Laboratory of Surface Physics in Eotvos University
1985-1986:	Head of Dept. Solid State Physic, Eotvos University Budapest, Hungary
1986-1987:	Research fellow Scottish Surface Centre, Strathclyde University, Glasgow, UK
1988-2004:	Appointed visiting professor to Material Engineering Department of Strathclyde University, Glasgow, UK
1996-cont.	Professor at St. Istvan University, Gödöllö, Hungary (biophysics)
2012-cont.	Appointed visiting professor, Pazmany Catholic University, Hungary (bioelectrodynamics)
2013-cont.	Appointed visiting professor at Chiba University, Japan (fractal physiology)

PRESENT ADMINISTRATIVE POSITIONS

2000-cont.	Head of Biotechnics Department in St. Istvan University, Faculty of Engineering. Hungary
2001-cont.	CSO of OncoTherm (www.oncotherm.de) (both the Hungarian and German Branches)

SCIENCE AWARD

2000	Dennis Gabor Award (Hungarian Academy of Science)

PUBLICATIONS

Author and co-author of about 700 publications (articles, conference contributions/abstracts), co-author of eight books, and co-author of 40+ patents