

Stevens S S & Galanter E H. Ratio scales and category scales for a dozen perceptual continua. *J. Exp. Psychol.* 54:377-411, 1957.
(Psycho-Acoustic Laboratory, Harvard University, Cambridge, MA)

People make numerical judgments about the perceived magnitude of physical quantities in several ways. Two of these yield psychophysical scales. These two scales are related to each other nonlinearly, but invariant across many sensory modalities. [The $SC7^*$ and the $SSC7^*$ indicate that this paper has been cited in over 595 publications.]

Subjective Expressions of Objective Reality

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In Harvard's Memorial Hall dungeon dwelt the master of psychophysics and psychoacoustics: S.S. Stevens, who was called "Smitty." Attended by a shifting crew of graduate students and research fellows (I was one of the latter), we scurried about under his whip to "measure, measure, and find the invariance; that's where the truth is." We were busily exploring ways to get people to tell us quantitatively about the perceived magnitude of their experiences. Didi Stone, his sometime research administrator and later his wife, suggested a new method, "Just ask people to give the experience a number." It worked! Subjects could do it, and their data were as clean and reliable as those drawn from any of the other methods we used. Simplicity does occasionally succeed.

This new method of "magnitude estimation" seemed to me and others just a refinement of the classical "category judgment" method described by Titchener and favored by L.L. Thurstone.¹ When that method was used, people were simply asked to sort quantitative experience into categories as, say, "on a scale from 1 to 10, etc...." These category scales had the nice property that when they were plotted against their corresponding physical magnitudes, a logarithmic relation emerged that confirmed G.T. Fechner's psychophysical law (1860).² But our magnitude estimation data were strange. The judgments people made about the magnitudes of the

stimuli we presented were not at all logarithmic, rather they were best described by a power function. That means that if you plot these psychophysical functions in log-log coordinates, the data can be fitted by a straight line whose slope represents the degree of sensory compression or expansion that people impose on that particular sensory continuum.

We first noted this mathematical truth when a visitor from California dropped by to show us how data from his studies of the perception of truck traffic "confirmed" Fechner's logarithmic law. He had plotted the logarithm of the judgments his subjects made against decibels and then drew a straight line over the data points. That line fitted the line precisely. As we quickly pointed out, decibels are themselves a log scale. Because he had also log transformed the dependent variable, his double log data actually rejected Fechner's law. He left the lab crestfallen, but promised to try pure magnitude estimation in his continuing research. Merely the exponents of the power functions we found were less than one—perceptual compression—as in brightness and loudness. Sometimes, however, e.g., the pain of electric shock, gave exponents greater than one, a rapid growth of perceived pain relative to the dynamic range of the shock.

So far we had explored an interesting and practical procedure to generate psychological scale values of physical stimulus magnitudes. Indeed, over the next 35 years, the methods of magnitude estimation were used to measure everything from the magnitude of crime³ to the value of money⁴ and other nonmonetary events.⁵ However, the data in this original paper yields what is in my opinion a more fundamental and theoretically central result. When magnitude scales are plotted against category scales, an invariant relation emerges. Category scale values are a nonlinear but systematically concave downward function of magnitude scales for one class of stimuli; those we called "prothetic." These are the stimuli that vary in quantity as though stimulation is added to stimulation. Examples of prothetic continua include loudness, brightness, sweetness, and other intensiveness aspects of stimulation. For dimensions of perception we called "metathetic," stimuli that differ in kind not amount, the psychological relation between the two kinds of scales was often linear. These psychological, as distinct from psychophysical laws, set the stage for new insights into the transduction of physical energy into their psychic effects and have revealed aspects of the relations between stimulation and reaction that transcend the Fechnerian orthodoxy.

1. Thurstone L L. A law of comparative judgment. *Psychol. Rev.* 34:273-86, 1927. (Cited 400 times since 1956.)
2. Fechner G T. *Elements of psychophysics. Volume I.* (Adler H E, trans.) New York: Holt, Rinehart and Winston, 1966. 286 p. (1860 edition cited 270 times since 1956.)
3. Sellin T & Wolfgang M. *The measurement of delinquency.* New York: Wiley, 1964. (Cited 390 times.)
4. Galanter E. The direct measurement of utility and subjective probability. *Amer. J. Psychol.* 75:208-20, 1962. (Cited 50 times.)
5. Galanter E. Utility functions for non-monetary events. *Amer. J. Psychol.* (In press, 1990.)