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# Hubris to humility: Tonal volume and the fundamentality of psychophysical quantities

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ABSTRACT

Psychophysics measures the attributes of perceptual experience. The question of whether some of these attributes should be interpreted as more fundamental, or "real," than others has been answered differently throughout its history. The operationism of Stevens and Boring answers "no," reacting to the perceived vacuity of earlier debates about fundamentality. The subsequent rise of multidimensional scaling (MDS) implicitly answers "yes" in its insistence that psychophysical data be represented in spaces of low dimensionality. I argue the return of fundamentality follows from a trend toward increasing epistemic humility. Operationism exhibited a kind of hubris in the constitutive role it assigned to the experimenter's presuppositions that is abandoned by the algorithmic methods of MDS. This broad epistemic trend is illustrated by following the trajectory of research on a particular candidate attribute: tonal volume.



*Not all facts are fertile.*

— E. G. Boring in 1962, reflecting on the decline in interest in tonal volume.

## 1. Introduction

Can perceptual experience be measured? Committed to the view that it can, psychophysics attempts this measurement indirectly, by inferring a quantitative model of experience from the reports or induced behavior of subjects in response to physical stimuli. The question of whether this model constitutes a measurement, and whether one should infer from it that there are quantitative aspects of experience, has been vexed, to say the least.[1]

Provisionally accepting these models as measurements, however, opens up a further array of interpretative questions. For instance: are all aspects of experience equally worthy of measurement? Or are some more "fundamental," scientifically significant, or perhaps even *real* than others?

I argue that these questions were suppressed in early 20th century psychophysics, but reemerged later in the century as a natural consequence of new methods for extracting quantitative models from psychophysical data. Suppression was implicit in the operationist program for defining psychological concepts: if the scientific legitimacy of a sensory attribute[2] rests entirely on the existence of an operation that consistently assigns it values, there seems little room for assessing some attributes as more fundamental, significant, or "real," than others. However, the rise of multidimensional scaling as a technique for extracting structure from data introduced a principled method for distinguishing fundamental attributes of experience from those that are merely derived or artifactual. Multidimensional scaling and related

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[1] One source of criticism turns on the phenomenological point that sensations do not seem introspectively to be relatable by numerical ratios, but are rather purely qualitative (e.g. James, 1890, i.546–9). A second line of criticism takes psychophysics to mistakenly attribute properties of the stimulus to the experience, the "stimulus error" of E. B. Titchener (Boring, 1921). More recently, Michell (1997) has argued that psychophysics has ignored the conceptually prior task of establishing that the qualitative axioms of quantitative structure are satisfied by sensory experience. See Marks and Algom (1998, 83–5) and Boring (1942, 44–5) for surveys; Stevens (1975, Chapter 2) gives a general response, while Barwich and Chang (2015) provide a spirited rebuttal of Michell in particular.

[2] A note on terminology: "attribute" and "quality" were at one point used as contrasting terms, both of which Boring (1933) advocated replacing with "dimension," appropriate if experience is treated geometrically. In order to emphasize the continuity in these issues from a modern perspective, however, I use the terms interchangeably, with a preference for "attribute" as it does not imply the contrast with quantity of "quality"—a contrast that would be inappropriate given that the psychological features at issue, even those labeled "qualities," are treated quantitatively by psychophysics.

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methods exhibit "epistemic humility" in the sense that they do not presuppose which (or even how many) attributes characterize a sensory experience. This contrasts sharply with the "hubris" of operationist psychophysics, which relied constitutively on presuppositions about the attribute of interest, as revealed most clearly in the instruction and training of subjects. This is ironic indeed given that operationism itself was responding to an earlier perceived hubris, and crisis, in psychophysics, turning in part on the vacuity of structuralist debates about the fundamental attributes. So, while fundamentality has oscillated in and out of theoretical importance, the trend toward humility has been largely monotonic: operationism embracing a more humble methodology than structuralism; multidimensional scaling emerging as a yet more humble alternative to operationism.

A full demonstration of this broad trend in sensory psychology is beyond the scope of this paper. Instead, I illustrate its influence in miniature through the example of a particular sensory attribute: *tonal volume*. Volume, the apparent "size" of a sound, emerges as an attribute of interest in the early 20th century, and in 1935 was offered by seminal operationist S. S. Stevens as a paradigmatic example of an "empirically meaningful" psychological concept. Nevertheless, interest in tonal volume waned throughout the 20th century, with more recent textbooks relegating it to passing comment, if mentioning it at all. By the lights of contemporary auditory psychology, volume is at best a quaint epiphenomenon, a historical footnote. I argue this rise and fall of volume is explained by the trend towards epistemic humility that allowed fundamentality to reemerge as a criterion of scientific legitimacy for sensory attributes.

The issue here is whether *within sensory experience* some attributes play a more fundamental role than others. Operationism, as practiced by Stevens and his advisor Edwin Boring, did allow that some attributes might be more basic than others, but not for reasons internal to sensory experience; rather, the relative significance of attributes could only be evaluated on physiological grounds. In the case of tonal volume, the fact that trained subjects cued to volume were able to consistently discriminate stimuli counted as evidence for the legitimacy of volume as a sensory attribute, but its relative importance compared to other attributes depended entirely on its conjectured physiological correlates. In contrast, multidimensional scaling derives fundamental attributes directly from psychophysical data. The fundamentality of these attributes is thus justified on purely sensory or behavioral grounds, independent of any physiological speculation. When applied to auditory experience, scaling methods fail to isolate volume as a fundamental attribute, hence its disappearance from the psychology of hearing.

Section 2 illustrates the operationist suspicion toward fundamental attributes exemplified in the historical work of Boring, while Section 3 outlines the history of tonal volume. The puzzle of volume's disappearance motivates an examination and critique of operationism in Section 4. I argue that the very logic Stevens employed to legitimate psychophysical measurement undermined operationism's ability to differentiate between fundamental and derived sensory quantities, or to identify the inconsistent data on volume from different labs as an omen of its theoretical fragility. Section 5 introduces multidimensional scaling, explicating its criterion for fundamentality, and arguing it exhibits epistemic humility. When auditory experience is approached with this humility, volume does not emerge as a fundamental quality. I conclude with some new challenges for realism about psychophysical attributes that follow from this trend toward humility. The methodology of operationism succeeded in ensuring a firm logical link between sensory attributes and physiological mechanism; in contrast, multidimensional scaling's enthusiasm for humility has left it without a clear foundational argument for how or why the fundamental sensory attributes it identifies are physiologically grounded.

## 2. Fundamental attributes in crisis

Edwin G. Boring's (1942) *Sensation and Perception in the History of Experimental Psychology* is not only an important history of early psychophysics, it is also a document of prevailing attitudes toward that history during the rise of research on tonal volume. Boring presents Stevens' research on tonal volume in the 1930s as exemplifying a "new phase" in the way attributes of sensation are treated in psychology (25–7), the implications of which he had already explored and defended in his own research (Boring, 1933, 1935). What was the stagnant research program that this new phase moved to replace? Boring (1942) portrays a number of cases where debates about which phenomenal attributes were more "real" (23), "simple" (130), "primary" (375), or "basic" (512) turned out to be meaningless, poorly defined, or simply irrelevant.[3] The most immediate target of this critique is the structuralist approach to psychology, but the breadth of Boring's attack implies a more general position, that no evidence from experience, introspection, or behavior could establish theoretical primacy of one attribute over another.

For instance: one of the most notorious rivalries in the history of psychology was that between Hermann von Helmholtz and Ewald Hering in the late 19th century. Although there were many facets to this rivalry, encompassing broad differences in theoretical commitments and methodology (Turner, 1994), one aspect that was perceived to turn on a point of fact concerned the number of primitive color sensations. Helmholtz argued for three—"red," "green," and "violet"—on the basis of his experiments on sensations of white induced by mixtures of spectral colors (Helmholtz, 1962 [1910], 143; c.f.; Lenoir, 2006; Isaac, 2013). Hering argued for four—red, green, yellow, and blue—on the basis of phenomenological observations,[4] for instance the color opponency effects revealed in experiments on afterimages (Hering, 1878, Report 6; Turner, 1994, pp. 130–4, 189–95); this position was then bolstered by work showing subjects are able to judge the degree of purity of the four Hering primaries.[5]

For Boring, there are two aspects to this controversy. On the one hand, there is a legitimate question about the neural correlates of behavior that receives a straightforward physiological resolution. Once we recognize that not all physiological processes relevant to a sensation need reside in the sensory organ—three processes corresponding to Helmholtz's primaries may reside in the retina, and, without contradiction, four (rather, two opponent) processes corresponding to Hering's primaries may reside in the brain—the dispute disappears. On the other hand, there is the question of which qualities of experience are simple or basic to its phenomenal

[3] Boring's attitude was indeed representative of the time: for instance, the very same examples discussed here are presented as confused, irresolvable debates in the founding manifest of behaviorism, Watson (1913). Stevens (1935a) does not cite specific examples, but offers the primary motivation for operationism as the resolution of ill-defined, and thus "useless" disagreements (c.f. Hardcastle, 1995). Feest (2005, 138–40) argues explicitly that Boring's perspective on history shaped Stevens' operationism.

[4] I've put the Helmholtz primitive colors in scare quotes, as for him the primitive qualities themselves may be "unconscious," or at least difficult to directly access in experience without training—the names for these primitive sensations are thus placeholders, derived from the experiences associated with the single wavelengths of light that most excite each to the exclusion of others, although such exclusive excitation is impossible in practice as the receptive fields for the corresponding receptors overlap. In contrast, Hering's primitive colors, in virtue of being directly accessed in phenomenological observation, unambiguously refer to everyday notions of red, green, etc.

[5] See Kuehni (2014) and Wright (2016) for surveys of issues related to pure (or "unique") hues.

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