Limitations of the physical correlate theory of psychophysical judgment

Michael H. Birnbaum

Department of Psychology, University of Illinois, Champaign, Ill. 61820

Warren's theory that judgments of subjective magnitude are mediated by an attempt by the observer to judge physical relationships is incomplete. While physical relationships in the environment may be an important factor affecting judgment, the physical correlate theory suffers several inherent limitations and does not yet have the empirical foundation one desires to see for a comprehensive theory.

The basic idea that subjects learn physical laws (such as the inverse square law relating light intensity and distance) can be tested by manipulating physical relationships to study changes that should be induced in the stimulus-response relationship. Manipulation of causal variables is preferable to looking for correlational implications, such as the claim that the exponent in the power function relating magnitude estimates to physical values should match the power function relating two physical values in a natural law. Manipulation of environmental physical laws can be accomplished by means of systextual design (Birnbaum 1975; 1981). For example, the relationship between intensity and distance could be manipulated in the laboratory to determine whether a linear (rather than inverse square) law can be induced.

The claim that estimates of loudness and brightness (or lightness) are related to physical intensity by the square-root function requires a rather selective review of previous research. First, sensory scales based on category ratings, subtractive models, and discriminability are not reviewed by Warren. These procedures yield results that contradict his conclusions. Presumably, they are assumed to be "biased," yet no theory to account for the bias is offered. Second, magnitude estimation studies yielding contradictory results must also be assumed to be "biased."

The conditions that Warren supposes to be "unbiased" appear to be based either on shaky armchair contentions or the circular argument that the desired result is obtained using that procedure. First, it is assumed that subjective estimates are a power function of physical value. Second, it is assumed that overt magnitude estimation responses are directly proportional to subjective value:

$$R = J[s], \tag{1}$$

where R is the overt response, and s is the subjective value (presumably mediated by an attempt to estimate distance), and J is the function relating responses to subjective values. Third, Warren assumes that J is the identity function when different groups of subjects judge different stimuli.

Suppose subjects in one group say the "ratio" of the lightness of 50% to a 10% reflectance square is "2" and another group of subjects say the ratio of 35% to a 10% reflectance square is "3." Warren would be forced to conclude that 35% reflectance is lighter than 50% reflectance, *even if every subject who sees both squares says the opposite.* Mellers and Birnbaum (see Birnbaum, in press) found that comparing responses between different groups can lead to such ordinal contradictions if the same J function is assumed for both groups. Birnbaum (1981) has argued that if different groups of observers have different J functions, even though they may have the same subjective values (s), then one cannot unambiguously compare responses between groups of subjects. Yet Warren recommends that a complete between-subjects design be used.

Warren assumes that judgments of "ratios" are indeed governed by a ratio operation. However, this assumption has been seriously questioned by recent studies (Birnbaum 1978; 1980; 1981; Birnbaum & Elmasian 1977; Birnbaum & Mellers 1978; Birnbaum & Veit 1974; Schneider, Parker, Farrel & Kanow 1976; Veit 1978; and others). For example, Birnbaum & Elmasian (1977) found that "ratios" of loudness were inconsistent with a ratio model if any power function is assumed. Birnbaum (1980) summarizes evidence that "ratios" and "differences" are monotonically related, consistent with the hypothesis that the same operation (possibly subtraction) underlies both tasks. Veit (1978) found a rank order of darkness "ratios" and "differences" that is inconsistent with the square-root function postulated by Warren. Birnbaum & Mellers (1978) found that the ratio model implies distorted mental maps of the United States. Thus, the physical correlate theory, as presented by Warren, is seriously threatened by studies that have cast doubts on the ratio model of stimulus comparison.

The subtraction theory leads to scale values for loudness and lightness that disagree with the square-root function, and no monotonic transformation of the data would permit one to retain the square-root function (Veit 1978; Schneider et al. 1976; Rule & Curtis 1981; Birnbaum & Elmasian 1977; Birnbaum 1981). Thus, even allowing for monotonic response "bias," a good deal of evidence shows that the square-root function fails to reproduce the rank order of the data. In sum, recent research shows that the ratio model and the power function are incompatible for loudness. Furthermore, if the subtractive model is assumed, then the square-root power function for loudness and lightness can be rejected.

Finally, physical correlate theory says nothing about the basis of subjective values on other continua, where physical correlates are not readily apparent. For example, most people say that they expect to like a person who is *kind* or *sincere* much more than a person who is *cruel* or *phony*. Subjects are willing to evaluate "ratios" and "differences" of likableness, and they can even be asked to judge "ratios of differences" (Hagerty & Birnbaum 1978). Does physical correlate theory imply that subjective values do not exist or are not accessible without a correlated physical dimension? If so, the theory is incomplete in that it fails to account for judgments on continua such as likableness.

In sum, it seems reasonable that the stimulus-response relationship in magnitude estimation can take on many forms depending on a number of factors, including perhaps some learned transfer from another stimulus-stimulus relationship. To test this limited physical correlate theory, one should *manipulate* the environmental law and look for a corresponding change in the stimulus-response relationship. In general, however, physical correlate theory relies on the assumption of an indefensible theory of "bias," it requires a questionable ratio theory for comparison, and it supposes a doubtful power function. Finally, it ignores the larger realm of psychological values that do not have obvious physical correlates. For these reasons, the physical correlate theory suffers severe limitations as a general theory of psychophysical judgment.

Direct judgments: Sensation or stimulus correlate?

Dwight W. Curtis

Department of Psychology, University of Alberta, Edmonton, Alberta, Canada T6G 2E9

I do not find the case for the stimulus-correlate theory, as presented by Warren, very convincing. His argument appears too much dependent on a causal inference from a correlation (between intensity and distance) in the physical world. There seem to be substantial reasons for questioning whether this correlation provides a basis even for evaluating distance, much less brightness.

In fact, distance and brightness are only two of many correlated variables that are relevant to our perception of distance (or depth). Others include accommodation, binocular disparity, absolute and relative motion parallax, and familiar and relative size. Size, as well as brightness, is inversely related to distance, and its "cue validity" (using Brunswik's (1966) term) for judging distance may be greater. In the usual psychophysical experiment, brightness is varied and size is held constant. It seems at least possible that in the absence of other cues to distance, perceived distance is ambiguous, at best. If one constrains more of these variables, the use of distance information for the representation of brightness seems a rather dubious proposition. Gogel (1978) notes two tendencies that apply to an observer's perception of depth in the absence of binocular disparity: the equidistance tendency and the specific distance tendency. The former refers to a tendency for objects to appear equally distant from the observer, and the second refers to a tendency in the absence of distance information for them to appear at a relatively small distance of 2 to 3 m. One might well question whether brightness variation would constitute a viable basis for the perception of depth when it was in conflict with the invariant values on these other variables.