CONTEXT EFFECTS AS FOUNDATION FOR UNIFIED THEORY

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ABSTRACT

Is unified theory possible? Unification has been lost to sight amid the increasing fragmentation of the psychological field. Unification may be possible, nevertheless, by primary focus on two problems that are fundamental in every area. These two problems are context-stimulus interaction and stimulus-stimulus integration. In principle, both problems may be solved jointly with algebraic models of stimulus integration. In practice, this integrationist approach has been reasonably successful across diverse fields of psychology. A key empirical result is that valuation and integration are distinct modules. Valuation modules allow for context-stimulus interaction, which is ubiquitous. Integration modules provide true measurement of context-stimulus interaction. Most important, these results imply that context effects provide a foundation for developing unified theory.

Is unified theory of psychology possible? This goal, advocated long ago by Fechner, has disappeared in the maelstrom of fragmentation that characterizes current psychology. This fragmentation has come to be accepted as normal. Mini-theories are plentiful, but mini-theories do not lead to unified theory.

FOUNDATION FOR UNIFIED THEORY

To attain unified theory requires conceptual reorientation, based on these two axioms:

Axiom of Purposiveness.

Axiom of Stimulus Integration.

Axiom of Purposiveness. The axiom of purposiveness is manifest in our sensory systems, most of which are affective, as with taste, temperature, and sex. These sensory systems embody a pleasure–pain axis that subserves reactions of goal-approach and goal-avoidance. Purposiveness thus confers a priceless simplification — by reducing complex reality to one-dimensional values of approach and avoidance. Although this one-dimensional representation omits much, it captures a central characteristic of perception, thought, and action.

Axiom of Stimulus Integration. The axiom of stimulus integration defines a key issue for unified theory. This axiom reflects the evident fact that all perception, thought, and action depend on integrated action of multiple stimuli. The "taste" of a food, to take an everyday example, depends on odor, temperature, texture, and visual appearance, as well as sweet-sour-salt-bitter. Quest for unification must thus seek general laws of stimulus integration — a focus on Fechner's inner psychophysics.

Measurement: A Critical Difficulty. A critical difficulty confronts the search for laws of stimulus integration. Linear (equal interval) scales of the stimulus variables, and of the response, are needed.

To illustrate, consider the hypothesis that the size−weight illusion obeys an addition law. The psychological sensation of heaviness is then the sum of the psychological sensation values of the two stimulus variables of weight and size:

$$\rho_{\text{Heaviness}} = \psi_{\text{Gram Weight}} + \psi_{\text{Size}} .$$

To verify this equation, we must be able to measure the three terms on true subjective scales. Without true psychological measurement, we cannot establish even this simple addition law. But if we cannot deal with this simple case, we can hardly hope to deal with more complex integration. This problem of psychological measurement has been controversial ever since Fechner's proposition that just noticeable differences are equal psychologically and can be used as additive units to determine psychological scales.

Functional Measurement Theory. The problem of psychological measurement has been solved in many situations with functional measurement theory. The logic of functional measurement is to use algebraic laws of stimulus integration as the base and frame for psychological measurement. The simplest form of functional measurement is the parallelism theorem for addition laws.

Parallelism Theorem. Let S_{Aj} and S_{Bk} be stimulus levels for two factors, manipulated in a two-way design. Denote their psychological values by ψ_{Aj} and ψ_{Bk}. Let ρ_{jk} and R_{jk} be the implicit and observed responses, respectively, to the stimulus combination, $\{S_{Aj}, S_{Bk}\}$. Two premises are employed:

$$\rho_{jk} = \psi_{Aj} + \psi_{Bk} ; \qquad \text{(Premise 1: addition)}$$

$$R_{jk} = c_0 + c_1 \rho_{jk} \qquad \text{(Premise 2: linear response scale)}$$

The linearity premise says the observable response, $R_{jk,}$ is a linear (equal interval) function of the implicit response, ρ_{jk} (here c_0 and c_1 are zero and unit constants that may be set at 0 and 1 for simplicity). Two conclusions follow:

Conclusion 1: The factorial graph will be parallel.

Conclusion 2: The row means of the factorial data table will be a linear (equal interval) scale of ψ_{Aj} ; the column means will be a linear (equal interval) scale of the ψ_{Bk} .

Note the simplicity of this parallelism analysis: Just graph the subject's responses and look.

Three-Fold Benefit. Observed parallelism provides support for three conjoint benefits.

1. True measurement of the psychological values of the stimuli.

Prior stimulus measurement is not needed. The functional stimulus values derive from Conclusion 2. Note especially that the psychophysical law follows directly from Conclusion 2. It is just the function that relates the sensation values provided by the parallelism theorem to the physical values of the stimuli. Success of the parallelism property can resolve the long controversy over the psychophysical law.

2.Exact structure of the integration law.

Observed parallelism supports Premise 1 of additivity. This is strong support although not absolute proof. Logically, it is possible that nonadditivity in the integration is exactly cancelled by nonlinearity in the response measure. This logical possibility no longer seems serious (Anderson, 1996, pp. 45*f*, 94-98).

3. True measurement of the response.

Observed parallelism supports response linearity (Premise 2). Response linearity is not an assumption; it is tested by the parallelism analysis. Response linearity has fundamental importance, as noted later under *Response Generality.*

Algebraic Psychology. Whether functional measurement will be useful depends on whether algebraic laws have empirical reality. The parallelism theorem has minor value unless Nature has endowed organisms with adding-type rules. Happily, extensive empirical work has revealed algebraic laws—addition, multiplication, and especially averaging—in almost every area of psychology.

To establish algebraic psychology faced serious obstacles. One obstacle was that by far the most common algebraic law is averaging, not addition. But averaging yields parallelism only in the special case of equal weighting. If two levels of a factor carry unequal amounts of information, the data will be nonparallel. Observed nonparallelism was not infrequent in the initial work, therefore, but it was ambiguous, for it could merely reflect nonlinear response. This seemed the more likely because we were using a rating method, which was universally condemned because of well-known nonlinear biases. The initial work was thus perplexing. Fortunately, this obstacle was overcome, in part by developing simple procedures to linearize the rating method. Indeed, some of the strongest evidence for functional measurement came from experimental manipulations of the weights and verifying predicted deviations from parallelism.

Conceptual Implications. Conceptual implications of algebraic laws are more important than measurement per se (Anderson 1996, p. 467). One conceptual implication is *value invariance*—the value of one stimulus does not depend on the other stimuli that are being integrated. This invariance property is implicit in Premise 1. If instead ψ_{Aj} depended on S_{Bk}, the data would generally violate parallelism.

Note that value invariance does not deny context effects. On the contrary. The axiom of purposiveness implies that the value of any stimulus is generally very sensitive to context. *Context-stimulus* interaction is thus ubiquitous. But *stimulus-stimulus* interaction during integration is relatively rare.

A related conceptual implication is that *valuation* and *integration* of stimuli are distinct operations, or modules, to use a current term. This independence of valuation and integration is a wonderful blessing of Nature; it provides a rock of stability in the sea of context-dependent values. This valuation–integration independence is a key to unified theory because it has a cutting edge with algebraic laws. Context effects, in particular, can provide new tools to study inner psychophysics.

CONTEXT

The contributors to this session all show that context effects are interesting in themselves. Contrary to Stevens' (e.g., 1971) position, context effects are not a nuisance in the way of measurement but instead "can provide a conceptual-methodological foundation for psychophysics" (Anderson, 1992, p. 98). Indeed, contextual stimuli are an important special case of the axiom of stimulus integration.

This capability appeared in the experimental studies that verified the foregoing addition law for the size-weight illusion. Functional measurement then yielded a validated scale of the sensation value of the gram weight (Conclusion 2 of the parallelism theorem), and thereby allowed determination of the psychophysical law. This jujitsu tactic is a form of theory control, analogous to that used in signal detection theory (Anderson, 2001, pp. 249*f* and 659*ff*).

For unified theory, context effects have central importance. In unified theory, the very term *context* is somewhat misleading. In most life situations, multiple stimulus cues are

directly relevant, as with taste of food or with music perception. No sharp boundary separates this class of situations from others that involve a sharp distinction between focal and contextual stimulus.

Unified theory must face squarely the axiom of stimulus determination including integration of so-called context effects. Although contextual effects are sometimes a nuisance, mostly they serve pertinent functions. Thus, the cross-modal size cue in the size-weight illusion embodies information that is ecologically relevant, even though only on a probabilistic basis. To call this an illusion reflects a narrow outlook that misses major aspects of perception, thought, and action in real life.

INTEGRATION PSYCHOPHYSICS

Integration psychophysics (IPP) represents a fundamental conceptual shift from traditional psychophysics. IPP begins in a different direction, and addresses a variety of issues that seem outside the reach of traditional psychophysics. Some of these are detailed briefly under the following subheadings.

Psychological Law Versus Psychophysical Law. IPP seeks Nature's laws in the integration operation—the *psychological law* (Anderson, 1970, Figure 1). Traditional psychophysics assumed without question that Nature's laws were *psychophysical law*—located at the interface between the external physical world and the internal psychological world. The only argument concerned the form of the psychophysical law, whether log law, power law, or something else. But the psychophysical law is inherently too narrow to solve its own central problem, namely, measuring psychological sensation.

The psychological law, in contrast, can measure psychological sensation. This follows from the parallelism theorem. For example, an algebraic integration rule for lightness sensation has been established; hence functional measurement provides a validated scale of lightness sensation. The psychophysical law is just the function relating these measured sensation values to the known physical reflectance. These data show an exponent near 0.3 in a power function, thereby demonstrating invalidity of Stevens' method of magnitude estimation, which yields an exponent of 1.2. This functional scale of lightness agrees reasonably well with Fechner's jnd scale and with the standard Munsell scale.

From the standpoint of IPP, the concept of psychophysical law has been a historic misdirection. Being a function of a single variable, the psychophysical law is inherently too narrow to provide a foundation for psychophysics/perception (Anderson, 1970, 1975, 1996, Chapter 9).

Nonconscious Sensation. That sensation is conscious has been taken for granted in traditional human psychophysics. But conscious sensation generally results from integration of nonconscious sensation. Analysis of nonconscious sensation is thus a central problem of psychophysics and perception.

Functional measurement can measure nonconscious sensation in some cases. It can dissect an integrated conscious sensation into components, some of which may be nonconscious. This capability was shown with the addition law established for the size-weight illusion. Conclusion 2 of the parallelism theorem then provides validated measures of the nonconscious, cross-modal effect of the size stimulus.

This capability for dissecting conscious sensation gives IPP one means to link up with the sensory branch of psychophysics (see below) and to pursue Fechner's inner psychophysics. Here again, traditional psychophysics has been too narrow, and has closed off important problems.

Nonmetric Stimuli. Psychophysical law is impossible for stimuli that lack a physical metric. But many such stimuli have psychological metrics. These psychological metrics can be determined by establishing an algebraic integration law. IPP has had some success in this

endeavor, for example with the contextual, visual cue of size in the size-weight illusion. Inability to handle nonmetric stimuli reflects a crippling narrowness of traditional psychophysics.

Hedonics. Most senses are affective, as with taste, temperature, and sex. Pleasure and pain are Nature's means of inducing purposive behavior. We should be grateful for our evolutionary legacy of affective senses.

Contextual cues are important in hedonics, which thus requires focus on stimulus integration. With hedonics, as with nonconscious sensation and nonmetric stimuli, the narrow scope of traditional psychophysics led to relative neglect of a central characteristic of perception, thought, and action.

Mixtures. Mixtures obviously involve stimulus integration, also largely outside the scope of psychophysical law. Taste is a prime example because taste depends on multiple stimulus determinants. Application of functional measurement by McBride showed that judged sweetness of a sweet-sour mixture obeyed an exact subtraction law. In sharp contrast, judgment of total intensity obeyed a configural, dominant component law, the judgment being governed solely by the stronger of the two components (see chapter by McBride and Anderson in Anderson, 1991).

Failure of Magnitude Estimation. Functional measurement is neutral in the controversy between rating and magnitude estimation. Both have equal opportunity to satisfy the parallelism theorem.

As it happened, the rating method has been widely successful, not only in psychophysics, but in almost every other area of psychology, including extensive work with children. A few simple procedures serve to eliminate the nonlinear biases. Our ideal method is graphic rating, which is considered to underly numerical ratings. Rating linearity is conjectured to derive from accuracy of motor movement in local space.

Each of these successes is also a failure of magnitude estimation. This follows from the well-known nonlinear relation between magnitude estimation and rating. This failure of magnitude estimation has been obscured by Stevens' smokescreen of double talk (e.g., Anderson 1981, pp. 333-347). Stevens' work on magnitude estimation is reminiscent of his work on somatotype theory, in which the astonishingly high correlations between personality and body build were unreal, merely personal bias by Sheldon and Stevens, who read their theory into their data (Anderson, 2001, p. 222). Stevens' successors, fortunately, have begun to acknowledge the necessity of algebraic laws as the base and frame for psychological measurement—the core idea of functional measurement (see e.g., Anderson, 1992, p. 104, 1996, p. 313).

Sensory Psychophysics. Sensory psychophysics is a flourishing domain, as with localization of visual function in the brain, but very different from the tradition concerned with the psychophysical law.

IPP works from the center outward, expecting to link up with sensory psychophysics that works from the periphery inward. One such link appeared with the addition law for red–green contrast. A gray test field adjacent to a red inducing field will appear tinged with green; an adjacent green field will appear even greener. In his thesis, Stefurak applied functional measurement and showed that this color contrast obeyed an addition rule (see Anderson, 1996, pp. 290*ff*).

Of special sensory interest, the results showed that a physiological red-green scale, defined by relative activation of red and green cones, was a true linear scale of conscious sensation. This followed from the linear relation between this physiological scale and the verbal judgment of red–green, the latter being validated by the parallelism theorem.

Direct Perception. IPP differs fundamentally from Gibson's (1966) theory of direct perception. IPP is constructed on a base of *internal structure*, especially algebraic structure of

integration laws. Direct perception, in contrast, is founded entirely on correct perception of external structure. Perceptual illusions are therefore considered normal information processing in IPP (e.g., Anderson, 1975), whereas direct perception "must explain incorrect perception by supplementary assumptions" (Gibson, 1966, p. 287).

Gibson's theory is extremely narrow; it says nothing about areas that lack an external standard of correctness. It is thus half-blind to affect, which is Nature's guide to perception, thought, and action (Axiom 1). It is similarly half-blind to language, person cognition, moral judgment, and other areas, all of which have revealed algebraic integration laws exactly like those found in psychophysics/perception. Gibson's theory exemplifies the harmful effects of the compartmentalization that afflicts psychology. IPP offers a unified approach (see further Anderson, 1996, Note 7, p. 313, Note 11, p. 315).

MEASUREMENT THEORY

Psychological measurement has been controversial ever since Fechner's 1860 claim that just noticeable differences are equal psychologically and so may be used as additive units to define sensation scales. Fechner's claim is attractive, but definitive evidence has been elusive.

Functional Measurement Versus Conjoint Measurement. Capability for true psychological measurement has been claimed by both functional measurement and conjoint measurement. Two differences between these two approaches deserve consideration.

1. Functional measurement focuses on continuous response. Conjoint measurement disallows continuous response as a matter of principle, allowing only greater than-lesser than choice response.

2. Functional measurement has been empirically successful in psychophysics and in diverse other areas of psychology. Conjoint measurement, in bleak contrast, has had virtually zero empirical success. The technical problems of analysis with choice data have never been overcome despite intensive efforts by workers of highest ability. This judgment appears in the verdict by Cliff, himself a onetime proponent of conjoint measurement, that conjoint measurement is the "revolution that never happened"(1992, p. 186, echoing Anderson, 1981, pp. 347-356; see also Anderson, 2001, pp. 734*f*).

Response Generality. Psychological measurement theory should have a primary goal of developing methods to obtain true measures of continuous response. Thus, the common rating scale, with a few simple precautions (see Anderson, 1996, pp. 92-98) has been found to provide validated scales of sensation and judgment across nearly every area of human psychology. This response methodology is why functional measurement succeeded where conjoint measurement failed.

Continuous response measures are essential; much integration will not obey any simple algebraic law. Many situations, perhaps most, cannot be handled with the parallelism theorem or its sister theorems for averaging and multiplication laws. But if validity of the response measure has been established, then pattern in the observable data will be a veridical picture of pattern in the underlying process. Methodology for linear response can thus be invaluable for analysis of configural integration. Response linearity does not make this hard problem easy, but it does give a foothold for analysis.

UNIFIED THEORY

Unified theory must be constructed on a base of structure of the internal world. This internalist approach contrasts with the externalist approach, which attempts to construct theory on a base of structure of the external world. The externalist perspective has been enormously attractive. Not only does the external world provide something definite to cling to, but survival requires substantial similarity of the internal world to the external world.

In psychophysics, this externalist approach is epitomized in the concept of psychophysical law. This concept assumes that Nature's laws are located at the interface between the external and internal worlds—that internal sensation is a simple, universal function of the physical metric of the external stimulus. But this assumption is far too narrow for unified theory. It cannot handle nonmetric stimuli, as already indicated, nor hedonics, nor nonconscious sensation.

It is no surprise to find externalist approaches everywhere (Anderson, 1996, pp. 449*ff*). This externalist tack appears in the monolithic conception of memory as reproduction of specified materials, quite ignoring the need for a functional conception of memory. In judgment–decision theory and signal detection theory, the dominant externalist tack attempts to force cognition into a straightjacket of optimal models. Even in developmental psychology, the externalist tack appears in Piaget's fundamental assumption that cognitive development is a development of isomorphism of the internal to the external world.

These externalist approaches have certainly been useful. In large part, however, that usefulness ended some time ago. Unfortunately, they have persisted far beyond their usefulness—a common fate for human ideas, trapping us in inadequate conceptual frameworks and closing off many important phenomena.

In psychophysics, stimulus integration is a time-honored conception, especially with study of context effects. This work, however, has remained fragmented and compartmentalized. Lacking methods of psychological measurement, the possibility of unified theory did not arise.

Unified theory is an empirical reality, thanks to an unexpected blessing of Nature in the form of algebraic laws of stimulus integration. The same concepts and methods used in IPP have been reasonably successful in almost every area of psychology, including judgment–decision, language processing, person cognition, developmental psychology, and even with rats and pigeons. What has been done is only a very small step. What has been done, however, is unified and general—cumulative science that shows promise as a base for further study of the inexhaustible treasure-house of Nature.

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