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Unified science based on psychological laws

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Two axioms are fundamental for psychological science:

Axiom of Purposiveness and *Axiom of Integration*.

The Axiom of Purposiveness is self-evident: All thought and action are directed toward goals. Treating purposiveness as an explanatory principle has been continually attractive but has continually foundered on teleological reefs.

The Axiom of Integration is also self-evident: Perception, thought, and action depend on integrated operation of multiple determinants. Understanding and predicting thought and action both depend, therefore, on theory that can deal with integration problems.

Both axioms are prime challenges for any attempt at general theory. Both pose difficulties. The Axiom of Purposiveness implies that physical stimuli must be represented in functional terms. The functional value of any stimulus is not in the stimulus. It must be constructed by the person, in relation to operative motivations and goals. The first difficulty is to determine these functional values for individual persons.

The Axiom of Integration implies that thought and action depend on simultaneous operation of two or more determinants. The second difficulty is to determine the law of integration. Both difficulties can be resolved, in some important cases, with the psychological laws of Information Integration Theory (IIT).

The following Integration Diagram summarizes the essential issues.

Integration Diagram

$$\{S_A, S_B\} \xrightarrow{V} \{\Psi_A, \Psi_B\} \xrightarrow{I} \rho \xrightarrow{A} R$$

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Given a field of physical stimuli, $\{S_A, S_B\}$, each stimulus is transmuted by an *integration operation*, *V*, into a psychological value, yielding $\{\Psi_A, \Psi_B\}$. These psychological stimulus informers are combined by an *integration operation*, *I*, to yield the implicit response, ρ. This internal response is externalized by the *action operation*, *A*, to yield the observable response, *R*. We must rely on manipulation of the physical stimuli and observation of *R* to deduce all three unobservables – the psychological informer values, the integration rule, and the implicit response.

Psychological laws

True measurement is necessary to resolve the problems posed by the Integration Diagram. Consider the simple addition law,

$$\rho = \Psi_A + \Psi_B . \qquad (1)$$

Such addition laws have been conjectured by many writers in diverse areas, but proving them faced an absolute barrier. All three quantities, ρ, Ψ_A, and Ψ_B are unobservable; to establish any additive rule requires true measures of these three unobservables.

The century-plus attempts to develop such measurement theory started in a plausible direction that turned out to be a blind alley. A new, functional direction was needed:

Use addition laws as base and frame for true measurement.

Previously, measurement had been considered *prerequisite to* establishing an addition law; in diametrical contrast, the functional direction makes measurement *derivative from* the addition law. Success depends on psychological reality of addition laws, but such laws have been solidly established in most areas of human psychology.

Parallelism Theorem

This new direction is illustrated with the parallelism theorem of functional measurement. Consider a two-variable integration experiment, in a standard row × column factorial design. Denote the physical row stimuli by S_{Aj} with psychological values Ψ_{Aj}; denote the physical column stimuli by S_{Bk} with psychological values Ψ_{Bk}. Each cell of the row × column matrix represents one stimulus combination $\{S_{Aj}, S_{Bk}\}$, the response to which is denoted ρ_{jk}.

Two premises are required for the parallelism theorem.

Premise 1: The addition law holds: $\rho_{jk} = \Psi_{Aj} + \Psi_{Bk}$.

Premise 2: The observed response is a linear function of the unobservable response, that is, $R_{jk} = c_0 + c_1 \rho_{jk}$ (c_0 and c_1 are zero and unit constants whose values are not generally needed).

Premise 2 connects the unobservable response ρ to the observable response R.

Although this theorem is mathematically simple, observed parallelism supports three strong conclusions:

Conclusion 1: The addition law holds: $\rho_{jk} = \Psi_{Aj} + \Psi_{Bk}$.

Conclusion 2: The action function, A, is linear: $R_{jk} = c_0 + c_1 \rho_{jk}$.

Conclusion 3: Row means of the data matrix are true measures of Ψ_{Aj}; column means of the data matrix are true measures of Ψ_{Bk}.

Empirical analysis is simple. Graph the row × column matrix of responses in standard row × column format. The column variable may be conveniently spaced at equal intervals along the horizontal axis; the vertical axis represents the observed response. Plot each row of data as a connected curve. These curves will be parallel, except for response variability, if the two premises are true. Conversely, observed parallelism is strong joint support for both premises. Indeed, the parallelism theorem supports six benefits that deserve itemization.

Six benefits of parallelism

1. *Addition Law*. This is Conclusion 1.

2. *Response Measurement*. The observed response is a true (linear) image of the nonobservable response by virtue of Conclusion 2.

3. *Stimulus Measurement*. True (linear) measures of the functional psychological values of the physical stimuli are available by virtue of Conclusion 3.

4. *Meaning Invariance*. The stimulus informers do not generally interact to change one another's meanings or values; such interaction would cause systematic deviations from parallelism in most experiments. This controversial issue was thus settled in a simple, definitive way.

5. *Cognitive Modules*. Valuation and integration are independent modules. Integration occurs after and is independent of valuation. This is a novel result about flow of information processing.

6. *Construct Validity*. Success of an addition model gives modest indication that the terms of that model represent real psychological entities.

The parallelism theorem is remarkable; it finesses measurement of the unobservable stimulus values.

Equation 1 might seem to require prior measurement of Ψ_A and Ψ_B. In fact, only a linear measure of ρ is needed, and this is attainable (Conclusion 2). This is a true finesse, moreover, because it captures the unobservable stimulus values; these are just the marginal means of the integration data (Conclusion 3). This measurement capability is essential for tasks in which direct measurement is impossible, when for example these values are nonconscious. Examples are given in Equations 2 and 3 below.

Independence of valuation and integration is a key. Values are infinitely variable for they depend on innumerable stimulus differences across situations and contexts. Also, values depend on knowledge systems and operative motivations of each individual. By virtue of independence, this infinite variety can be handled with a few general purpose integration processes. The integration laws are thus ecologically efficient. And, as illustrated with the six benefits of the parallelism theorem, these laws are a beachhead on science of psychology.

Of course, parallelism is not absolute proof of additivity. Logically, nonlinearity in the response measure might just cancel nonadditivity to yield net parallelism. Although this logical possibility should not be forgotten, it is no longer of much concern (Anderson, 1996, pp. 94ff).

Besides the addition law, two other integration laws have been extensively supported. Multiplication laws obey a linear fan theorem, as with the classic example, Subjective Expected Value = Subjective Probability × Subjective Value. Averaging laws, actually the most common, can be more complicated, but have the perhaps unique capability of measuring importance weight separately from value (Zalinski & Anderson, 1991). Present discussion, however, is mainly limited to addition laws, technical issues omitted.

Conscious and nonconscious

Constructionist theory of consciousness may be possible with the psychological laws. Conscious experience is an integral of idiographic values of multiple stimulus informers at largely nonconscious levels. The psychological laws can dis-integrate conscious experience to obtain true measurement of each separate informer – including nonconscious informers.

True measurement of conscious and nonconscious

Construction of consciousness may be illustrated with the size-weight illusion. Conscious heaviness of lifted weights follows an adding-type law,

$$\text{Conscious Heaviness} = \text{“Size”} + \text{“Weight,”} \quad (2)$$

where the quote marks represent subjective values that correspond to visual appearance and gram weight of the lifted weight.

The size-weight integration graph yielded parallelism, good support for the adding-type law (Benefit 1 of the parallelism theorem). Also, parallelism implies that the observed response is a true measure of the nonobservable conscious experience (Benefit 2). The psychological laws thus resolve the long-standing problem of true measurement of conscious sensation.

Furthermore, true measurement of the nonconscious also becomes possible. The functional values of both stimulus informers are nonconscious. What reaches consciousness is their integral. Indeed, subjects are generally unaware that the visual appearance influences their experience of heaviness. The integration laws, however, can dis-integrate conscious experience to reveal its nonconscious determinants (Benefit 3). This capability of functional measurement is a new methodology for consciousness theory (see also *Intuitive physics* below).

Looking forward: Identity assumption

An identity assumption, that conscious sensation is an identical image of any underlying nonconscious sensation, had been an article of faith in the field of psychophysics. Analogous assumptions are common in other fields, for example, in emotion. These assumptions are attractive because they seem to make conscious experience a sufficient base for general theory.

Such identity assumptions are automatically suspect as soon as the Axiom of Integration is appreciated. Conscious experience is generally an integral of multiple determinants and need not be simply related to any one. The heaviness sensation produced by the gram weight is itself nonconscious. The cited experiment establishes an identity, namely, that conscious heaviness is linearly related to nonconscious heaviness. This identity is not an assumption, however, but an implication of the empirical law. In other integration tasks, conscious and nonconscious experience could be disordinally related.

Looking forward: Analytic theory of consciousness

Analytic theory of consciousness may be possible with the psychological laws. The size-weight study suggests the potential of integration theory, but this is only one experimental situation. How far this approach may go is an open question.

This empirical approach differs from the most prominent theme in current discussions of consciousness. This theme is whether consciousness

can be understood in terms of brain processes or whether conscious experience involves something essentially different. This theme is reminiscent of bygone controversies over vitalism, which were only resolved through empirical investigation. The constructionist capabilities of the psychological laws can help similar analysis of conscious experience without prejudging the issue and without wasting time on undecidable speculation (see *Nonconscious personality* below).

Information integration learning theory

Learning is conceptualized as information integration in IIT. The psychological laws, however, embody a broader view of learning than traditional theories of reproductive memory or conditioning.

A nonassociative, constructionist base for human learning is implicit in the Integration Diagram. Traditional learning theory has followed the British associationist philosophers, with learning conceptualized as internalization of external stimulus-response contingencies. This associationist view is clear with Ebbinghaus' pioneering studies of rote memory, Pavlov's conditioned reflexes, and Skinner's bar presses. Such associative learning is ecologically vital, of course, but it is a lesser aspect of human cognition.

The need for nonassociative, information theory of learning begins with the Axiom of Purposiveness. The functional value of any stimulus informer depends on its relation to whatever goal is operative. The same informer may have entirely different values, therefore, relative to different motivations and goals. These functional values are more important for learning than any memory for the stimuli themselves.

The need for constructionist theory of learning is reemphasized by the Axiom of Integration. Multiple informers must be valuated and integrated to construct a response; this short-term learning may be transferred into long-term memory for future use. These integrals are more important for learning than any memory for the stimuli themselves. Indeed, these integrals may have entirely different quality from the physical stimuli.

Dissociation in learning

This informational view of learning was precipitated by an early experiment in which subjects judged likableness of a person described by a list of trait adjectives and then gave casual recall of the adjectives. At that time, it was an article of faith that the judgment at any later time would be determined by the verbal memory of only those adjectives that could be recalled.

The results showed quite otherwise. A dissociation was found: Adjectives that were best recalled had least effect on the judgment. This dissociation between stimulus and response has been well supported.

This dissociation implies that traditional theories have secondary relevance for human learning. What is learned is a two-stage construction – first, construction of goal-relevant implications of physical stimuli, and second, an integration of these implications. Stimulus-response contingencies may have minor relevance. Reinforcement may have no relevance.

Once this information processing view is appreciated, it seems quite obvious. The cited task of person cognition is just one of many examples of information learning theory. Our beliefs and attitudes about our spouse and colleagues, about research issues, even about our self, develop from valuation-integration processes that are little recognized in traditional learning theory. The psychological laws make information integration theory of learning empirically effective.

Looking forward: Belief learning

The psychological laws can be used to construct learning curves for beliefs. The cited task of person learning, for example, can be considered as learning a belief about likableness. Belief learning curves can be constructed that reveal how much the stimulus informer on each successive trial influences the final response – even when only the final response is given. This capability with learning curves opens new opportunities for traditional learning theory, especially capability with complex stimulus fields. Also, it helps unify learning theory with judgment-decision theory (see Schlottmann & Anderson, 2007).

Looking forward: Education

Adaptive transfer is the crux of education. A century ago, Latin and logic were considered the foundation for adaptive transfer. I myself had nonuseful Latin in school, when I might have had useful Italian. But a century after Thorndike's experimental demonstration that transfer is quite task-specific, learning theory has gone little further. Nor has education; concern with transfer in schools and colleges hardly goes beyond the final exam.

Serve the Student is the proper goal of education. Education should aim to teach students what they will need to know in later life. Three problems must be addressed. Find out what students do need to know in later life. Find out what they actually transfer from what they are currently taught. Find ways to teach for better transfer. The first two problems are

terra incognita. The third has been an earnest concern of many dedicated teachers. But little definite is known.

Learning theory needs a new direction, a direction that focuses on everyday life. The grim fact is that a century of massive research on learning has contributed almost nothing to education. The integration laws are one modest means for pursuing a new direction (see *Life-long learning*, Chapter 23 in Anderson, 2001).

Affect and cognition

Affect is information for living. The Axiom of Purposiveness impresses an approach-avoidance axis on thought and action. This approach-avoidance axis begins with affective sensory systems such as taste, warm-cold, and pain. It is greatly extended in humans to include diverse personal and interpersonal affects such as self-esteem, friendship, and dedication to a cause.

The biological nature of man implies that affect is integral to cognition. Contrary views have been common, especially with an opposition between affect and reason. One major group of cognitive psychologists explicitly disavow affect (see, e.g., Newell, 1990), a view once popular even in social psychology. This problem-solving tradition represents a very narrow view of cognition, quite inadequate for psychological science, in which affect is life energy.

The need for unified treatment of affect and cognition may be illustrated with the concept of Subjective Expected Value. This depends on integration of affective Subjective Value and nonaffective Subjective Probability – an affective cognition. The multiplication model of the next section illustrates the analytic potential of unified theory. Similar information/affect unification appears in the weight/value representation of averaging theory.

Looking forward: Affect theory

The integration laws provide a base for a general theory of affect because they can handle the two problems of valuation and integration in the Integration Diagram. Typologies of affect can achieve analytic power through study of contextual, goal-oriented function. Experienced affect usually depends on integration of values of multiple informers. The integration laws can provide true measures of experienced affect. They can go deeper; they can dis-integrate experienced affect to get true measures of each

component informer. Although these laws apply only in some cases, they provide analytic power not possible with other approaches.

Motivation and emotion are important in affect theory. Decision dilemmas, as one example, seem a promising domain for studying human motivation, for they embody approach-avoidance conflict that may be amenable to the integration laws. Social motivation may be more fruitful than the common focus on biological motivations. Emotion in everyday social interaction, as in family life or political issues, may similarly be more fruitful than biological motivations. Impressive work by Armando Oliveira has shown the usefulness of functional measurement in the field of emotion, especially with integration analysis of facial Gestalts.

Cognitive theory of judgment-decision

The field of judgment-decision is unique in its concern with optimal behavior. Algebraic models are common. Cost-benefit calculations should rationally follow addition-subtraction rules. Expected value of a chance event should equal chance-times-value. Many workers treat such optimal models as a cornerstone for normative theory of judgment-decision. This normative framework of optimal behavior currently predominates in the judgment-decision field.

This normative framework is negative for cognitive theory, a misdirection for psychological science. People are not generally optimal; deviations from optimality shed more dark than light on cognition. Indeed, the main outcome of normative theory has been innumerable "biases" – deviations from optimality. Few "bias" studies, however, have much cognitive significance. They merely show the normative model is cognitively invalid; deviations from an invalid standard cannot tell much about cognition. "Biases" can be important in practical situations, of course, as with medical diagnosis, but effective study requires field situations. Most studies, however, use simplistic laboratory tasks of dubious generality.

Looking forward: Judgment-decision as psychological law

Positive theory of judgment-decision is possible with IIT. The psychological laws are laws of cognition. To illustrate, the normative law of mathematical expected value led naturally to conjectures of a corresponding cognitive law of subjective expected value,

$$\text{Subjective Expected Value} = \text{Subjective Probability} \times \text{Subjective Value}.$$

Analogous Expectancy × Value conjectures have been common throughout psychology. They remained untestable conjectures, however, owing to lack of capability for measuring the three subjective terms in this model.

This measurement roadblock was removed with the linear fan theorem of functional measurement. This is much like the parallelism theorem, except that multiplication implies a linear fan pattern in the integration graph. Extensive experimental evidence, even with young children, warrants the term, multiplication *law*. This multiplication law is cognitive, however, not normative. This nonnormative character is underscored by appearance of this multiplication law in situations in which it is counternormative (Anderson, 1996, pp. 327ff).

The averaging law is a second example. It implies that adding a positive good can actually decrease the value of the whole. This is a nonprobabilistic disproof of the sure-thing axiom, once considered a rock-solid base for judgment-decision theory. This averaging law is positive; it describes much actual cognition in every area of psychology. And it has the perhaps unique benefit of allowing true measurement of importance weight in addition to value.

Looking forward: Three issues in judgment-decision

IIT is positive: It aims to study how people actually do judge and decide. The negative focus on "biases" can be replaced by a positive framework that focuses on underlying cognitive process. The multiplication and averaging laws just noted illustrate the effectiveness of this positive framework. It is an open question, of course, how far this approach will extend to more complex problems of judgment-decision.

A second issue concerns value. Values are life energy for judgment-decision, yet values are essentially extranormative. This capability with values was illustrated in the foregoing study of Subjective Expected Value, which lies beyond the reach of normative theory, well illustrated in cogent work by James Shanteau, Michael Birnbaum, and Lola Lopes. Functional measurement capability with values opens a new horizon for judgment-decision.

One need for value measurement appears with multiattribute analysis, a standard technique in applied situations, as with environmental impact statements and diverse commercial decisions. In principle, multiattribute analysis is simple: Identify the relevant attributes, calculate the weighted sum of attribute values for each alternative course of action, and choose that with the largest sum. This approach is optimal, just what is desired.

But such multiattribute analysis depends on true measurement of weights and values – which are essentially extranormative. Measuring these weights and values has relied almost entirely on makeshift methods – even though nearly all comparisons of different methods have shown marked disagreement among them. This disagreement is serious because different methods can lead to different decisions.

It is important, therefore, to develop valid methods of measurement, especially self-measurement, for use with multiattribute analysis. Functional measurement provides a base, used with promising results by James Shanteau, James Zalinski, Shu-Hong Zhu, and Ming-Shen Wang. These functional values provide a validity criterion against which to test and refine the common makeshift measurement.

Unified theory is a third issue, with manifest promise. Judgment-decision processes operate in every domain of psychology; judgment-decision theory should be a universal aide, illustrated in psycholinguistics by Gregg Oden and in child development by Anne Schlottmann and Friedrich Wilkening. But no normative standard of optimal behavior is present in most areas, such as psychophysical hedonics and social judgment. The normative fixation sidetracked the judgment-decision field away from fulfillment. *Respect the Phenomena* should be the first rule in judgment-decision theory.

Functional theory of attitudes

Attitudes pervade thought and action of everyday life, so much so that they often go unnoticed. Concepts and categories are classic issues in learning theory and in cognitive psychology; attitudes are little recognized although they are at least as important.

Attitudes are a modus operandi for the Axiom of Purposiveness. Attitudes function in valuating stimulus informers along the goal axis of approach-avoidance. Attitudes are one of Nature's devices for adaptive transfer of previous experience to present thought and action.

Social attitudes have been the major issue in social psychology. A functional conception of social attitudes was advocated in the 1950s, but this went little further than simple typologies of functions, such as ego-defense and social interaction. The importance of this functional approach has been universally recognized, but progress has been nil. The roadblock was lack of analytic theory that can go deeper than surface typologizing. This is possible, in some cases, with the capabilities for valuation and integration conferred by the psychological laws, an effective base for func-

tional theory of attitudes. This functional orientation is pursued with the following issues.

Looking forward: Person versus persuasion

Functional theory is person centered; it studies how attitudes function in everyday thought and action of individual persons. In sharp contrast, most work on attitude theory has focused on persuasion and changing attitudes. Such persuasion-centered theory, however, mainly studies "nonattitudes".

This persuasion-centered approach originated from early work on social attitudes, which was much concerned with prejudice toward minority groups, then and still a major social problem in the American "melting pot" of diverse ethnic groups. This meritorious concern had an unfortunate consequence; it led to neglect of those very attitudes involved in prejudice. The reason is simple: Such social attitudes are well-established, notably hard to change. To demonstrate persuasion/change in laboratory experiments, social psychologists were inevitably led to study "nonattitudes" – casual issues of minor importance that were susceptible to change. Some interesting results have been obtained but, as prominent researchers have complained, "nonattitudes" miss the main problem.

Well-established attitudes of everyday life can readily be studied with the laws of information integration. The key is to focus on how well-established attitudes function. Function and structure of real attitudes are both amenable to analysis with integration designs, as with moral attitudes below. The efficacy of this integrationist approach is indicated by the success of the three psychological laws in attitude studies by Margaret Armstrong, Cheryl Graesser, Clyde Hendrick, Samuel Himmelfarb, James Jaccard, Anita Lampel, Etienne Mullet, and María Teresa Sastre.

Looking forward: Attitudes as knowledge systems

Attitudes are considered *knowledge systems* in IIT. They develop through functional learning as discussed above. Most current definitions, in contrast, consider attitudes as one-dimensional, good-bad evaluative reactions. This one-dimensional conception has been continually reinforced by formal theories of attitude measurement, especially Thurstone's theory of pair comparisons.

This "nontraditional" view of attitude as knowledge system follows naturally from the Integration Diagram. Attitude knowledge systems function in valuating stimulus informers to construct attitudinal responses in particular situations. Context must also be taken into account. The same

behavior may elicit quite different reactions when exhibited by a woman than by a man. These short-term memories may be transferred to long-term knowledge systems for future use. Such capability with ever-changing motivations and contexts makes IIT a dynamic, contextual theory, as is necessary to study cognition.

Looking forward: Profile analysis

The advantage of conceptualizing attitude as knowledge system may be illustrated with attitudes toward women. One standard scale was constructed using factor analysis to ensure a single, good-bad dimension, in line with the customary definition of attitude as one-dimensional evaluative response. This scale may be useful as a rough social index, but it obscures the full nature of attitude as adaptive knowledge system.

Profile analysis is an alternative. Foul language may be judged worse in a woman than a man by persons who favor absolute equality in the workplace. Each of the numerous social roles of women elicits a different facet of underlying attitude. A profile of such reactions can be obtained with functional measurement, a foothold for studying both function and structure of underlying knowledge systems. Profiles are also one approach to studying social roles, much discussed in sociology but surprisingly neglected in psychology. More generally, profile analysis is one approach to understanding *quality* of experience (see *Quality and quantity* in the next section).

Looking forward: Moral algebra

Moral cognition is an ideal field for attitude theory. Moral attitudes are typically well-established yet readily studied by experimental manipulation of pros and cons of moral dilemmas. This study of function can avoid the barren ground of "nonattitudes". Work to date points to a general moral algebra, studied by Arthur Farkas, Clifford Butzin, Wilfried Hommers, Manuel Leon, Colleen Surber Moore, Etienne Mullet, and John Verdi.

This moral algebra may be illustrated with the averaging law for blame. Judgments of blame for a harmful act depend on both the damage caused by the act and on the intent of the actor:

$$\text{Blame} = \text{Intent} + \text{Damage}. \qquad (3)$$

Deliberate injury is thus blamed more than accidental.

Blame is so common in everyday life that we may not appreciate its cognitive complexity. Damage in Equation 3 must be valuated personally by the individual blamer; this may include intangible damage such as loss

of face. Intent is not a physical stimulus, moreover, but must be attributed in a preliminary integration by the blamer.

Yet the parallelism theorem has the power to verify the averaging law using only observations of Blame. Furthermore, it can dis-integrate the blame judgment to measure both unobservable components, Intent and Damage. Many other moral judgments also follow algebraic laws, including recompense, forgiveness, obligation, and fairness.

Moral cognition can help reverse the proliferating fragmentation of psychological science. Moral cognition is no less important in personality than in social psychology, but almost as much neglected. Moral motivations are also prominent in socio-legal systems, studied by Wilfried Hommers and Yuval Wolf. Judgment-decision processes are vital, another base for unification. Substantial work has been done on moral development, but this work would also benefit from analytic capabilities of IIT.

Integration psychophysics

The integration laws solve the long-standing problem of measuring psychophysical sensation (see historical overview by Masin, 2003). *Psychological law* thus replaces the long fixation on Fechner's *psychophysical law*, which was inherently inadequate for this, its proclaimed purpose. Indeed, the parallelism theorem solves not only the problem of stimulus measurement (Benefit 3) but also the no less important problem of response measurement (Benefit 2). And it establishes an integration law as well (Benefit 1).

Functional measurement has been applied to quite a few psychophysical integration tasks, including taste, loudness, lightness, red-green contrast, velocity, optical illusions, and even pain. The potential of this approach was illustrated with the size-weight study under Conscious and Nonconscious. Cogent contributions have been made by many workers including Daniel Algom, John Clavadetscher, Robert Frank, Hans-Georg Geissler, Larry Marks, Sergio Masin, Dominic Massaro, Robert McBride, Peter Petzold, and David Weiss.

Looking forward: Quality and quantity

Quality of experience deserves systematic study. Quality is an essential complement to the monolithic focus on quantity. The question of quantity only arises after some quality has been defined. Quality, too much taken for granted and neglected, raises fundamental questions. Factor analysis and multidimensional scaling have been disappointing. Some new

direction is needed. Profile analysis seems important for recognizing the multiple qualities of many experiences of everyday life.

Psychophysics of "taste" seems promising for experimental analysis. Besides the basic senses of sweet, sour, salt, bitter, and odor, taste experience also involves crunchiness, moistness, temperature, and visual appearance. How all these qualities are integrated into experience is a basic issue. Study of professional wine tasters, taste panels in food industries, as well as everyday "foodies," would seem useful. The psychological laws can help through capability for nonconscious analysis and by developing valid methods for self-measurement. Some applications of these laws have been made in taste psychophysics, but more extensive phenomenological analysis seems an essential preliminary to help understand what needs to be done.

Intuitive physics

Intuitive physics, which had an illustrious adumbration in the *Accademia dei Lincei* of renaissance Italy, has exceptional value for cognitive theory. Events with dynamic structure become basic units of thought and action, temporal units that can enrich the common concern with static stimulus fields. Many physical stimulus parameters are readily manipulable, which facilitates experimental analysis. Language demands are minimal in many tasks, which facilitates developmental and cross-cultural comparisons. The psychological laws have shown promise in applications by a number of investigators.

Looking forward: Operating memory

Many integration tasks are performed so readily that operating memory is taken for granted. To illustrate, consider a task of intuitive physics in which a pendulum is released to strike a ball at the bottom of its descent, driving the ball up an incline. Subjects predict how high the ball will roll up the incline. Three mental models must be assembled into operating memory: The first governs the momentum acquired by the pendulum; the second governs the transfer of momentum to the ball; the third governs the movement of the ball up the incline.

Each of these three mental models involves the three operations, valuation, integration, and action, of the Integration Diagram. Thus, the momentum acquired by the pendulum will depend on valuation and integration of its height, mass, and length. Beneath its seeming simplicity, this task involves complex cognition. Such tasks offer many advantages for experimental analysis.

Looking forward: Nonconscious analysis

Intuitive physics has special interest because two response modes may be studied in parallel: verbal and motor production. In the cited pendulum task, for example, subjects may be asked to give a verbal judgment of how far the ball will roll up the incline or to actually place the ball at that distance.

Many cognitive abilities presumably arise out of motor skills, as with the method of functional rating. The verbal-motor dissociation between these two discovered by Friedrich Wilkening (e.g., Krist, Fieberg, & Wilkening, 1993) promises leverage into this developmental relation. Of similar interest is a dissociation of velocity-type judgments found by Algom and Cohen-Raz (e.g., 1984). This work has special significance for the general problem of event perception (see *Configural wholes* below).

Looking forward: Education

Physics education faces problems of negative transfer from intuitive physics, as with the common belief that heavier objects fall faster. Intuitive physics may thus provide opportunities for psychologists to contribute to the fundamental problem of education – adaptive transfer.

Developmental integration theory

A new framework for developmental psychology is provided by the three psychological laws. These laws are operative in young children and have brought new insight into children's minds.

Information integration theory and Piagetian theory

The efficacy of these integration laws appeared in the very first experiments. Basic tenets of Piagetian theory were found entirely incorrect. Piaget claimed, for example, that young children cannot integrate conceptual informers; instead, they "center" and judge on the basis of one informer alone. On the contrary, integration graphs immediately revealed that young children can integrate very well. Indeed, these integrations follow exact algebraic laws.

Piaget's basic framework was his stage theory, which claims that children develop through discrete stages, each of which restructures and replaces the previous stage. Instead, integration experiments reveal general continuity in development.

These integration studies were positive. They showed that young children have cognitive capabilities far greater than previously recognized. They give a unified framework, moreover, that can be applied across every area of development from intuitive physics to belief learning and social judgment.

Looking forward in developmental psychology

Virtually every area of developmental psychology offers opportunities for integration experiments. Studies of moral development have shown continuity instead of the popular theories based on discrete stages. In the judgment-decision field, Anne Schlottmann's (e.g., 2000) fine work has revealed good understanding of probability and expected value. Manuel Leon, Etienne Mullet, and Colleen Surber Moore have done cogent studies of social judgment. The importance of intuitive physics was shown by the ground-breaking studies of Piaget, which have been carried forward by several workers on IIT, especially Friedrich Wilkening. Developmental psychologists emphasize the importance of developmental analysis for understanding function and structure of developed cognition in adults. The integration laws, operative already in young children, provide an approach with analytic power.

Psychological measurement theory

It may seem surprising that the parallelism theorem, so simple and so effective, was not utilized long ago. One reason is that it assumes metric response measures, generally ostracized in psychological measurement theory because they suffer well-known nonlinear biases. Functional measurement theory succeeded by developing simple experimental procedures, mainly end anchors and preliminary practice, to eliminate these biases and obtain valid metric response.

A second reason was that psychological measurement was typically considered *prerequisite* to establishing an addition law. Functional measurement succeeded by reversing this direction to make measurement *derivative* from the addition law (Benefits 2 and 3 of the parallelism theorem). Psychological measurement is thus an organic component of substantive theory. The true foundation of psychological measurement lies in empirical studies by many workers in many fields that have established these laws on solid empirical ground.

Other measurement theories

Metric response has been anathema to almost all other theories of psychological measurement; they insist absolutely on nonmetric, greater than/less than, choice response. This nonmetric direction once seemed sensible, even essential, to avoid nonlinear biases of metric measures such as ratings or response times. Many mathematically ingenious schemes have been developed, the most notable being conjoint measurement. But despite four decades of intense efforts of high mathematical ability, conjoint measurement is unable to measure anything at all. Success required metric response – conjoined with experimental analysis.

A different reason is that lack of capabilities for metric measurement forced experimental psychologists to largely bypass integration theory and develop alternative issues and problems. Much has been learned in this way, but it led to modes of thinking and to intellectual fixation that do not appreciate the analytic power of the integration laws. It also led to makeshift attempts to handle stimulus integration that were often just wasted work.

Looking forward: Metric response

Metric response raises several issues for further work. One concerns cognitive processes involved in the action operation of the Integration Diagram. The rating response, being a relative judgment, rests on comparison processes that are considered to involve the decision averaging law. More penetrating study of this problem has been initiated by Sergio Masin.

Nonverbal response needs systematic investigation. A few studies with money bets have followed the integration laws but systematic study of this and other nonverbal response measures is needed. With rats and pigeons, response rate has done well in the few integration experiments that have been done. Many other nonverbal response measures deserve consideration.

Response generality is a notable advantage of metric measurement theory. A response method that has been validated in some situations may be expected to be valid in others. The method of functional rating should thus be generally useful by virtue of response generality. Factorial-type design to validate the response measure may not be necessary, therefore, which can thus be used when such design is costly or impossible. Similar work on behavioral and physiological response measures may be rewarding, although they may require monotone functional measurement to develop a standard response transformation. This issue of response generality shows that the prime goal of psychological measurement theory is to develop methodology for metric response.

Looking forward: Self-measurement

People can be asked for direct judgments of value and weight of each separate stimulus informer in an integration task. There may be no alternative in applied multiattribute analysis, as one example. The problem concerns the validity of these judgments. Functional measurement studies of self-measurement have shown promise for judgments of value, but mixed results for judgments of importance weight, which some subjects seem to confuse with value extremity. These experiments illustrate how the psychological laws can be used to develop valid methodology for self-measurement, much needed in multiattribute analysis and in consciousness theory.

Operating memory

An operating memory is needed to control purposive behavior. Assemblage of operating memory for any goal may begin with a provisional mental model of a path to the goal that needs to be fleshed out with mental models of steps to the goal. One mental model underlies the valuation operation, which will generally involve similarity between stimulus informer and goal. A second mental model appears with the integration operation. The occurrence of the three integration laws across so many different areas argues that they are stored as ready tools that may be assembled into operating memory for the task at hand, illustrated with the pendulum task in Intuitive Physics above.

The present concept of operating memory is similar to that of central executive in other information processing theories. However, the Axiom of Integration provides a different theoretical base. This difference may be illustrated by comparing IIT with Newell's (1990) attempt to develop a unified theory of cognition, which focuses on step-wise plans in problem solving. In his final summary, Newell explicitly recognizes that his approach has no place for affect or for metric response. But affect and metric response are both fundamental aspects of cognition. Effective footholds on both are available with the psychological integration laws.

Unification of the information integration laws with problem solving approaches is desirable. Assemblage processes, in particular, seem analogous to the step-wise structure of problem solving approaches. Such step-wise analysis may also be useful for studying action operations that have spatiotemporal structure.

Interaction and configurality

The three psychological laws embody a basic property of one class of integration tasks, in which valuation and integration represent independent processes, or modules. This independence is a key to true psychological measurement, a wonderful beneficence of Nature.

Of course, independence will not hold in general. In some tasks, separate informers will interact to change one another's value/weight parameters. Other tasks may involve configural patterns in the stimulus field. Getting definite evidence on interaction/configurality, however, is fraught with pitfalls. Statistical interactions from analysis of variance, for example, may well be artifacts of a nonlinear response (see *Understanding interactions*, Chapter 7 in Anderson, 2001). Some progress on studying true interactions has been made in IIT.

Looking forward: Halo theory

That stimulus informers interact to change one another's meanings seems self-evident in certain tasks. In one much-studied task of person cognition, subjects judge likableness of hypothetical persons described by a list of trait adjectives. The phenomenological feeling that the meaning of each adjective depends on the other adjectives is overwhelmingly compelling. But phenomenology is obstinately wrong about cognitive process.

If meaning change did occur, integration graphs would show systematic deviations from parallelism that stem from semantic/pragmatic interactions between individual pairs of adjectives. Instead, parallelism has been the standard result in many such experiments. The compelling feeling of meaning change is a phenomenological illusion. As this case shows, integration laws can play vital roles in general interaction theory (Anderson, 1981).

This analysis went further to explain the phenomenological illusion of meaning change as a halo effect. The overall judgment of the person reacts back on the post-integration judgments of individual adjectives. This halo process involves a flow of information processing quite different from that implied by meaning change. This diagnosis of information flow illustrates how algebraic laws can help elucidate nonalgebraic cognition.

Looking forward: Quantifying configural stimuli

Configural stimuli can be quantified with functional measurement in some cases. One method is to include them as units in a higher-order integration task. In one experiment, females judged date attractiveness of males

described by a photo and a pair of personality traits. The averaging law was verified for the photo-trait integration. Hence the functional values of the photo could be exactly measured. Such holistic values could help understand how individual features, such as lips, chin, nose, hair, and makeup influence the perception of the whole. Even an approximate integration rule could be informative (see *Configural wholes* in the next section).

Analytic Gestalt psychology

The psychological laws of information integration may arguably be considered Gestalt laws. They yield unified percepts as integrals of heterogeneous stimulus fields. The Gestalt movement of the early 1900s markedly broadened the psychological field by emphasizing holistic perception.

Unfortunately, this emphasis on wholes led to Gestalt aversion to analysis in terms of parts. This emphasis was a reaction against the particular conceptions of parts then dominant in German psychology which, in part because of these criticisms, are long obsolete and today almost meaningless. Systematic unification of Gestalt ideas with experimental analysis is desirable.

Laws of Gestalt phenomena

Algebraic laws have been established for some perceptual phenomena, the base field of Gestalt psychology. The holistic size-weight illusion obeys the adding-type law of Equation 2: Heaviness = "Size" + "Weight". Success of this law shows that physical size and gram weight are not merely physical stimulus determinants; they become transformed into genuine psychological parts (Benefits 3-6 of the parallelism theorem). Furthermore, this law can measure nonconscious sensation in some cases, a unique contribution to holistic analysis (see *Conscious and nonconscious* above). The psychological laws thus represent analytic holism.

Algebraic laws have even been demonstrated for Wertheimer's phenomenal movement, in which successive flashes of two lamps a certain distance apart appear as though the light itself moves through the intervening space – psychological motion without physical motion. These algebraic laws represent apparent motion in terms of parts, namely, the distance between the lamps and the time between the flashes. This line of inquiry has intrinsic interest, as well as potential for deeper understanding.

Looking forward: Face and music Gestalts

Face stimuli have acted as unit wholes when paired with trait adjectives in person cognition. The functional, holistic values of these faces could thus be exactly measured with the averaging law. These values could help study how individual features, such as eyes and mouth, influence perception of the whole, for example, with judgments of attractiveness or memory familiarity.

This approach can go beyond the standard concern with face recognition. Recognition is a minor aspect of face cognition in everyday life. From other's faces, we seek to judge their character, their moods, what they think about us, what we think about them. Functional measurement can help study everyday functions of face cognition.

Similarly interesting is the addition law for music found by Makris and Mullet (2003). Functional values of music variables such as timbre and rhythm are surely configural. But the additive law, timbre + rhythm, makes it possible to measure these holistic values for individual persons. Music integration laws are a new approach in studying psychology of music appreciation, surprisingly neglected as Makris and Mullet observe.

Looking forward: Configural wholes

Two approaches to configural wholes deserve consideration. One is to study effects of parts on wholes, as just indicated with face cognition. The integration of such parts into a whole may involve essentially new processes of perhaps greater interest than the algebraic laws. These laws can help, however, by providing true measures of the whole and through nonconscious measurement.

A second approach concerns events with temporal structure. Some such events will be processed as a sequence of separate units that may be integrated by an addition law, for example in belief learning about a person through biographical description or during personal interaction. One foothold for experimental analysis may be possible by combining likely stimuli in a serial integration design. Absence of interaction would indicate independent units and allow their measurement. Presence of interaction would provide evidence on configurality.

Looking forward: Value as fact

The Axiom of Integration might perhaps be considered the Axiom of Gestalt; integration subserves all unified perception. In addition to cognitive algebra, some progress has been made on configural integration (see

Interaction and configurality). And irreducible wholes may sometimes, as already noted, be treated as unit parts in a higher-order integration.

Fact versus *value* was the central theme of Köhler's (1938) thoughtful critique of (then) contemporary psychological science, much of which remains pregnant today. Science, he claimed, was concerned with fact, not with value; but value was the essence of life. The psychological laws can measure value for individuals in context – *Value* becomes *Fact*.

Person science

Person is the basic issue for psychological science. To develop person science requires unification of all areas of the field. These areas are fundamentally incomplete without such unification.

So fragmented is the psychological field, however, that the person has almost disappeared from sight. This loss of the person appears in the widespread neglect of individual differences: Learning, memory, attitudes, and developmental, among other areas, usually deal with group means. This approach calls to mind the stale tale of the four blind men who sought to study the elephant by each concentrating on one part (trunk, ear, leg, tail).

Trait theories of personality do claim to study the whole person, it is true, but this claim is negated by the small correlations of predicted and observed behavior. These low correlations are no surprise; the traits are generated from group data and standard analysis relies on correlations across groups. Person science must be able to study the individual person.

The psychological laws offer a new approach. The large individual differences evident in everyday preferences and values can be recognized with the idiographic capabilities of these laws. Unification with other areas of psychology becomes feasible, including learning, judgment-decision, developmental, and especially social psychology.

Looking forward: Laws versus typologies

Typologies are a common approach to personality, most obviously with trait theories. But typologies have limited usefulness. They block understanding of the need to deal with the two basic issues of valuation and integration in the Integration Diagram. They rely on group data, moreover, which can be appropriate for practical outcome analysis but does not get far with the idiographic person. This limitation is recognized in person × situation approaches but these go little further than typologies of situations. For person science, typological approaches are seductive but deeply unsatisfying.

The psychological laws, in contrast, apply to individual persons. These nomothetic laws have idiographic capability for both valuation and integration. They also have capability for analysis within specific environmental situations and contexts. These laws are basic in functioning of personality.

Looking forward: Functional person theory

How does personality *function* in everyday life? This is the concern of functional approaches. Person cognition, social attitudes, group dynamics, and moral values, are all important in personal functioning. Some efforts at unification have been made, as in social learning theory and prosocial development. For the most part, however, these listed areas, although primary loci of personal functioning seem insensitive to personality.

This insensitivity appeared in the earlier contrast between popularity of "nonattitudes" and neglect of well-established attitudes. Well-established attitudes are major parts of what a person ***is***. Person science should be integrated with attitude theory – and conversely. This insensitivity to the person is underscored by the neglect of moral attitudes both in attitude theory and in personality theory.

Other areas are no less important. Foremost is learning. Learned attitudes and social roles are central in personality. The same holds for other knowledge systems, including our knowledge systems about other persons in our life. These opportunities offer a new horizon for learning theory (see *Information integration learning theory* above).

Judgment and decision are involved in all functioning, as with functioning of attitudes and roles in the many choice decisions of everyday life. Processes and capabilities for judgment-decision begin developing in infancy, where they can be usefully studied to help understand adult cognition. Affect, emotion, and motivation are heart's blood in personality. Person science should seek unification with all these areas.

In turn, these areas can all enrich themselves by embracing person science – the prime domain of psychology. These opportunities are obscured in the autocatalytic fragmentation of our field. Unified theory requires new modes of thinking.

Looking forward: Nonconscious personality

Most approaches to personality rely heavily on conscious report. Freud emphasized the unconscious, but sought to bring the unconscious into consciousness where it could be dealt with. The heavy reliance on conscious report is apparent in the widespread use of personality tests, questionnaires, and interviews.

Personality is considered largely nonconscious in IIT. This view appears in the conception of person in terms of knowledge systems. Nonconscious components of an integrated conscious report can be exactly measured in some cases, as with the foregoing halo effect – footholds for studying personality function and structure.

Conscious report can be invaluable for nonconscious analysis. However, capability for nonconscious analysis is essential because (a) much is inaccessible to consciousness, (b) much is nonverbalizable, and (c) conscious reports are often invalid. Developing methodology for valid self-reports is important for person science (see *Psychological measurement theory* above).

Looking forward: Personal experiments

Experimental analysis of single persons is fundamental for person science. The necessity for experimental analysis is clear with the Axiom of Purposiveness, whose primary function lies in valuating stimulus informers in relation to operative motivations and goals. Person A cannot be understood in terms of the values of Person B.

Personal design goes further to personalize an experiment to each individual. Levels of each stimulus variable are chosen to be specifically relevant to that person, as has been done with integration studies of womens' marriage satisfaction (Anderson, 1981, 1996). Personal design unifies idiographic value with nomothetic law.

Unified psychological science

The two axioms, Purposiveness and Integration, stand as challenges to progress in every area of psychology. An analytic foothold is available with the three laws of information integration. These capabilities have been empirically successful in most areas of human psychology, illustrated in the foregoing overview. This generality warrants the term *law* (Silverberg, 2003).

Valuation and *integration* are both fundamental problems for psychological science. Integration presents the obvious difficulty that thought and action depend on multiple stimulus informers. Valuation presents the obvious difficulty that values of stimulus informers are psychological constructions that differ across individuals and across context.

Almost miraculously, these two problems have a simple solution in the psychological laws. These integration laws represent order and simplic-

ity at a deeper level than the multiplicity of stimulus variables. These same laws operate in nearly every area of the psychological field. The unending diversity of stimulus fields can, in many cases, be studied with a few general purpose integration laws.

These integration laws also give analytic footholds on the Axiom of Purposiveness because they can measure functional values of each element of complex stimulus fields. The long-desired goal of true psychological measurement becomes possible. These nomothetic laws allow exact, idiographic analysis of single individuals – psychology with a person face.

The psychological laws can help reverse the proliferating fragmentation of the psychological field. This fragmentation results in good part from standard strategy for attacking the Axiom of Integration, namely, manipulating multiple variables and seeking order in the results. Much has been learned with this strategy, but it leads away from unification. Instead, it increases fragmentation because observed effects of any one variable usually depend on specific values of other variables. Any one variable, moreover, will have different values for different individuals. As more is learned, prospects of unification recede ever farther.

Unified science is possible because the integration laws have general validity. Learning/memory can be liberated from the narrowness of conditioned response and reproductive memory to study functional memory of everyday life, especially learning of beliefs, attitudes, and values. Judgment-decision can take its proper place in thought and action across all psychology. Social-personality can be liberated from its narrow base on group means and correlations to become true person science. Developmental psychology can be unified with all these areas because these same laws appear also with young children, and because, updating Wordsworth, the child is parent to the adult.

Unified science is both hope and reality. It is a real hope because these three integration laws give simple analytic capabilities with the unending diversity of stimulus fields and individual differences. This reality has been demonstrated in dedicated efforts of many investigators whose work has been overviewed here (see also 51 contributors to IIT listed in *Dedication*, p. v in Anderson, 1996). The excellence and diversity of contributors to this Padova symposium are impressive evidence for such unification. The cogent contributions of these dedicated individuals open a new horizon in psychological science.

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Abstract

Unified science of psychology is possible with the psychological laws of information integration. These laws solve the long-sought goal of true measurement of psychological values. These laws apply to single individuals – nomothetic laws for idiographic understanding. These laws have made worthwhile progress in nearly every area of human psychology: judgment-decision, learning/memory, psychophysics/perception, developmental, and social-personality. These laws constitute a unified foundation for psychological science, with unique analytical power.

Riassunto

Una scienza unificata della psicologia è possibile grazie alle leggi psicologiche della integrazione della informazione. Tali leggi permettono di raggiungere l'obiettivo a lungo cercato della misura vera dei valori psicologici. Queste leggi si applicano ai singoli individui – leggi nomotetiche per la conoscenza idiografica. Queste leggi hanno generato progresso proficuo in quasi ogni area della psicologia umana: giudizio-decisione, apprendimento/memoria, psicofisica/percezione, sviluppo, e personalità sociale. Queste leggi costituiscono un fondamento unificato per la scienza psicologica, con potere analitico unico.

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