Information Integration Theory: Unified Psychology based on three mathematical laws*

Teoría de la integración informativa: psicología unificada con base en tres leyes matemáticas

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Psychology is unique among the sciences in its joint concern with dual worlds: (a) ***internal world*** of feeling and thought, and (b) ***external world*** of stimulus and response. The first major movement in psychology, the introspectionist movement of the late 1800s, took the inviting direct attack of studying the internal world with conscious report. Introspective methods, however, led to disarray. They were replaced by an intolerant behaviorism that allowed only observables of the external world. Many important results were thus obtained as with animal conditioning and rote learning.

Some liberation from behaviorism has developed since 1950, with social attitudes, emotion theory, and computer models of cognition. Overall, however, the result has been continued fragmentation of the psychological field into largely insular areas, all of great interest, but with little progress on unifying the internal and external worlds.

Fortunately, a unified approach is possible based on three mathematical laws of information integration. These are laws of the internal world. They relate unobservables of the internal world with observables in the external world. These integration laws have done well in almost every area of human psychology, from affect, motivation, attitude, and person cognition to learning, perception, and judgment-

decision. They are jointly *nomothetic* , holding across age and culture, and *idiographic* , allowing personal values of each individual person (Anderson, 2013, 2015).

Mathematical laws of thought and action

Mathematical psychology is a solid reality. Three simple mathematical laws—adding, averaging, multiplying—have been demonstrated in experimental studies in most areas of human psychology, from psychophysics and learning, to social attitudes and moral judgment. These three laws allow for personal values of each individual person. They hold generally with young children and adults, and they have been demonstrated in nations around the globe.

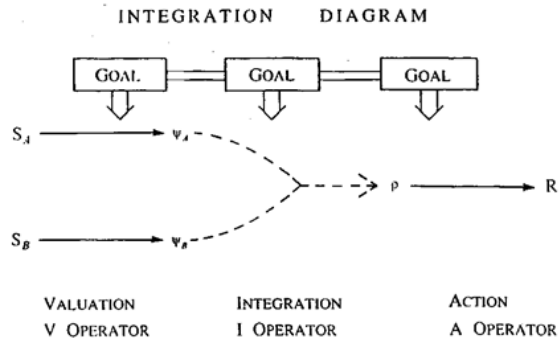
Dreams of mathematical laws have haunted the imagination of many psychologists. Some have presented hopeful equations as early as Aristotle's equation for fair division between two persons, A and B, working on some mutual project: share for A ÷ A's Contribution = share for B ÷ B's Contribution. A simpler conjecture applies to the judgment of blame, ubiquitous in society, from family to politics: Modern judgment-decision theory is grounded on the SEV law: Subjective Expected Value Subjective Probability ´ Subjective Value.

Psychological measurement is the critical obstacle towards testing such conjectures. All three terms in the blame equation, for example, are personal values in the blamer's head. Thus, Responsibility may be imputed by the blamer to the one being blamed on the account of carelessness or lack of forethought even though no actual harm was caused. Psychological measurement is thus necessary to test this blame hypothesis. We must get inside the blamer's head to measure his/her personal values of all three terms. The same applies to several other hopeful equations of thought and action that have been proposed.

Integration diagram

The essential ideas of Information Integration Theory (IIT) are given in the Integration Diagram of Figure 1 and in the Parallelism Theorem for adding-type integrations. In Figure 1, external stimuli, denoted by S, impinge on the organism and are transmuted into goal-directed psychological values, y. These internal values are integrated into an internal response, r, which is externalized to become an observable response, R.

Figure 1
Information integration diagram



Chain of three operators, V – I – A, leads from observable stimulus field, {S}, to observable response, R. *Valuation operator* , V, transmutes stimuli, S, into subjective representations, y. *Integration operator* , I, transforms subjective field, {y}, into internal response, r. *Action operator* , A, transforms internal response, r, into observable response, R (after Anderson, 1981).
Source: own work

The effectiveness of this approach depended on two things. First, on the development of the method of functional rating response (see Appendix A), which eliminates well-known biases of ordinary rating methods and validates Premise 2 of the parallelism theorem below; and Second, the miraculous beneficence of Nature which endowed the mind with three simple algebraic laws of stimulus integration.

Parallelism Theorem

Analysis of adding-type integration models, such as the foregoing blame equation, is given by the

parallelism theorem. Two stimulus informers are presented in an ordinary row ´ column factorial design. The subject responds to each cell in this design as illustrated in Figure 2 below.

The parallelism theorem requires two premises. Premise 1: The internal integration is additive: $r = y_A + y_B$. Premise 2: The action operator is linear: $R = c_0r + c_1r$. (Here c0 and c1 are inessential zero and unit constants.) These two premises imply that the row ´ column graph of R will show parallel curves (see following figures).

Observed parallelism thus provides a cornucopia of benefits. Benefit 1. Support for an adding-type model (Premise 1). Benefit 2. Support in favor of R as a true linear measure of internal response, r (Premise 2). Benefit 3. Support that the mean response in row j (column k) of the integration design is a true measure of y_{Aj} (y_{Bk}). Benefit 2 solves the long-standing obstacle of true measurement of *response* . Benefit 3 solves the obstacle of true measurement of *stimulus* . This is called *functional measurement* , because it measures the values that functioned in the integration process.

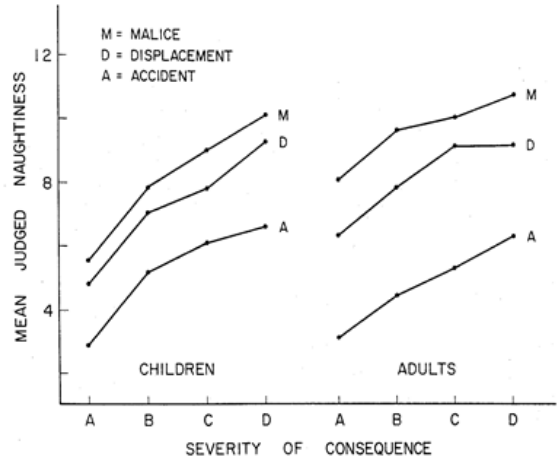
Empirical applications

The three mathematical laws of Information Integration Theory have done well in almost every field of human psychology, from judgment-decision and learning to social attitude theory, person science, and moral judgment. A few examples of adding-type laws are noted here.

Blame . Blaming follows an adding-type law even in young children as shown by the parallelism in Figure 2. Subjects judged an amount of blame for a child who threw a rock with specified intent (malice, displacement, accident) that caused four degrees of harm to another child (horizontal axis). The parallelism supports the additive law: Blame = Harm + Responsibility.

This blame law has been confirmed and extended by several investigators. It holds in legal judgment (Anderson, 2015, Chapter 4). A similar integration law holds with fair shares in adults and children as young as 4 years of age (Anderson, 2015, Chapter 5).

Figure 2
Parallelism supports the averaging law: Blame = Harm + Responsibility



Graph plots rated naughtiness of a story child who threw a rock with one of three intents (curve parameter) producing one of four levels of harm (horizontal axis). Left panel shows third-, fifth-, and seventh-graders; right panel shows college students. No age trends except perhaps the apparent increase in main effect of Intent (after Anderson, 2008).
Source: own work

Piaget's stage theory of child development, as well as that of Kohlberg, had thus been shown to be seriously invalid. Stage theories claim that development falls into more-or-less discrete stages, claims that can be extremely seductive. But Piaget and Kohlberg both relied on verbal rationalization of choices in moral dilemmas, a fatal mistake that was revealed as soon as the methods of Information Integration Theory were applied.

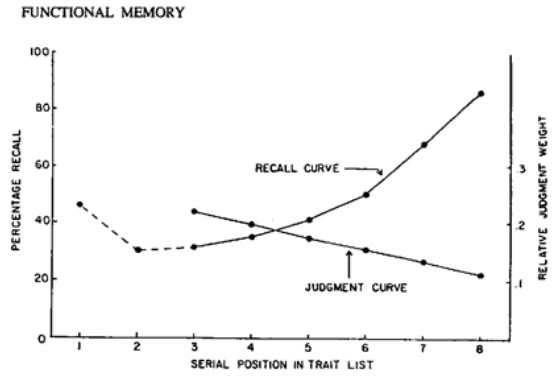
Functional memory versus Reproductive memory . An essentially new conception of memory emerged from the integration laws. Traditional memory research took for granted that memory was *remembering* —accurate reproduction or recognition of given material to be memorized.

This traditional view was universally accepted. In social attitude theory, for example, it was long an "article of faith" that the attitude

produced by a message was determined by what of the message remained in memory.

Instead, a *dissociation* between attitude and memory was found in a 1963 experience on IIT (see Figure 3). The recalled data showed the standard *recency effect* : the later items in the message were better remembered. In sharpest contrast, the earlier items had the greater effect on the attitude produced by the message items —a *primacy effect* . This dissociation has been widely supported.

Figure 3
Functional memory differs conceptually and empirically from traditional verbal memory

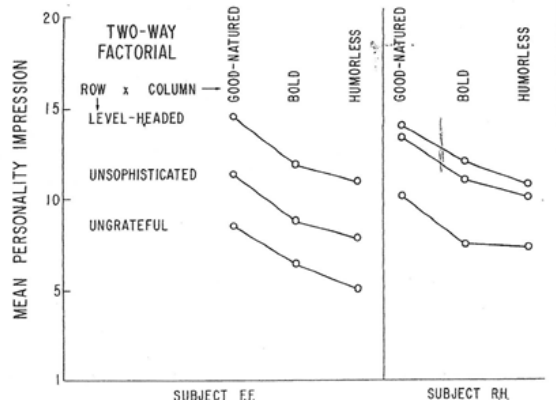


Recall curve for the adjectives in person description shows strong recency over last six serial positions, a standard result. *Judgment curve* for the effect of these same adjectives in person cognition shows uniform primacy, with lesser effects at later serial positions. Contrast between recall recency and judgment primacy implies a basic difference between person memory and verbal memory (after Anderson, 2015).
Source: own work

What is important in cognition are the *values* of the stimuli, as constructed by the *goal-directed* valuation operation in the Integration Diagram. These values function in the response. Such *functional memory* should be a primary concern of memory theory.

Person cognition . Interpersonal interaction is ubiquitous in everyday life: family, work, politics, and TV. Person cognition has been studied in numerous studies of experiments on information integration. In its simplest form, a hypothetical person is described by a set of trait objectives; the subject judges, for example, the likeability of the person. Figure 4 summarizes judgments of social desirability of hypothetical persons described by two of their traits, listed in the figure. The parallelism reveals simple adding-type integration.

Figure 4
Parallelism pattern supports adding-type rule in person perception



Subjects judge the likability of hypothetical persons described by two trait adjectives from an indicated Row ´ Column design. Each of these 3 ´ 3 = 9 person descriptions corresponds to one data point. Data averaged over third adjective for simplicity (after Anderson, 1981).
Source: own work

Consciousness gives a very different picture. People strongly feel that trait adjectives interact to change one another's meaning. Thus, *preoccupied* might seem to have a different meaning in an *earnest* person than in an *unproductive* person. Not a few researchers have strongly agreed.

But the parallelism implies that each adjective had a constant value—relative to the operative goal, regardless of which other adjective it was paired with. This *meaning invariance* was verified in other experiments in which subjects wrote a paragraph describing the person in their own words before rating the person. This would destroy the parallelism if the adjectives interacted to change one another's meanings.

But parallelism was still obtained, as shown also by other investigators.

This result also shows how integration theory can go below consciousness in the analysis of

cognition. Indeed, nonconscious influences can be exactly measured (Figure 6).

Science of Phenomenology . Phenomenology can be made scientific with the integration laws. The idea that the mind can be analyzed with verbal report has remained popular despite the failure of the early introspection approach. Indeed, verbal report is the medium of everyday communication.

However, the failure of verbal report, even in the simple experiment of Figure 4, shows that it can be quite untrustworthy. This crux can be resolved with functional measurement theory; the successes of the integration laws validate the method of functional rating (Benefit 2 of the parallelism theorem). These laws make it possible to develop the science of phenomenology.

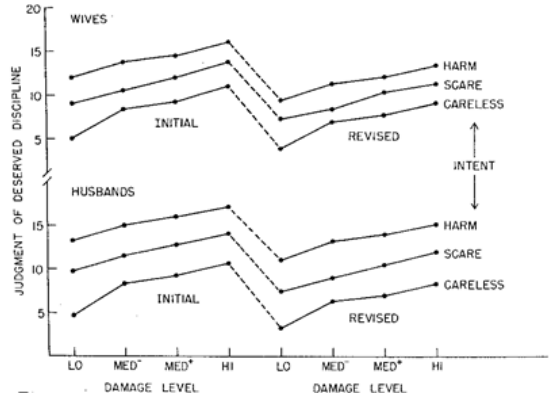
Cognition unitization and marital interaction . Complex stimuli can be treated as cognitive units, exactly measureable, by the integration laws. The valuation operation may be quite complicated, but its end result is a single number that can be exactly measured with an integration law.

One illustration of cognitive unitization comes from a study of wife–husband discussion. In the first phase, both spouses received a common scenario in which a child had performed a harmful action with a certain intent. Each spouse made a private judgment about the badness of this action. Next, husband and wife received separate, private information, slightly negative for one spouse, moderately extenuating for the other. They then discussed their own opinion and their added information with each other. Finally, they made private, revised judgments of badness.

Results are shown in Figure 5. The left side shows the private initial blame judgments, separately for wives and husbands. The parallelism of the three curves supports an adding-type law: Blame = Damage + Intent. The right side shows the private revised judgments, somewhat lower because the main information added in the wife–husband discussion was extenuating. Both spouses again show parallel curves, further support for the blame law.

Figure 5

Independent judgments of blame by husbands and wives



Initial judgments based on information about intent (curve parameter) and damage (horizontal axis). Revised judgments based on additional information presented by spouse.

Lo, Med^{-}, Med^{+}, and Hi represent graded levels of damage (after Anderson, 2015).

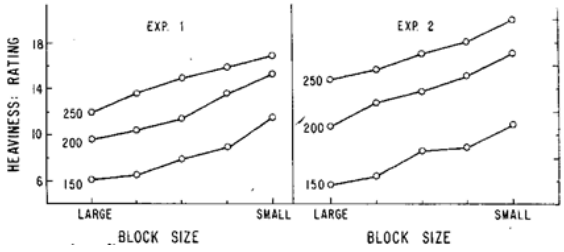
Source: own work

The wife–husband interaction thus acted as a *cognitive unit* for each separate spouse in the judgment of blame even though this verbal interaction was very complicated, beyond detailed analysis. Hence, it could be numerically measured separately for each spouse (see *Studies of Marriage* in Anderson, 2008).

Cognitive unitization has also been demonstrated in other experiments, for example, with judged statesmanship of U.S. presidents described by biographical paragraphs, and with witness testimony in a jury trial. Cognitive unitization is invaluable because it allows exact analysis of complex stimulus fields and complicated mental processing.

Measuring the Nonconscious . Most cognitive processing is nonconscious or semiconscious. It can be exactly measured, however, by using integration experiments. A simple example from psychophysics is the size–weight illusion of Figure 6.

Figure 6
Parallelism supports adding-type rule for size-weight illusion



Subjects lift and judge heaviness of cubical blocks in 3 ´ 5, Gram Weight ´ Block Size design. Verbal rating in left panel, graphic rating in right panel. The slope of the curves provides a true linear measure of the nonconscious heaviness effect of visual size. (after Anderson, 1981).
Source: own work

The top curve in each panel shows the judged heaviness of a lifted 250-gram cubical block of five different sizes. The upward slope of the curve shows that the same 250-gram weight feels substantially heavier in a smaller size. (Use an ounce of white feathers and an ounce of lead for a sure-fire class demonstration.) The parallelism of the three curves supports an adding-type model: Heaviness = Size + Weight.

But people are hardly aware that their conscious experience is influenced by the irrelevant size, much less that this nonconscious effect can be exactly measured. The integration laws thus provide a foundation for science of nonconscious cognition.

Multiplying Laws: Linear Fan Theorem

Multiplying laws follow a *linear fan theorem* , similar to the parallelism theorem. This application of functional measurement successfully solved the long-standing conjecture: Subjective expected value = Subjective probability + Subjective value.

Multiplying laws have also been found in many areas: poker betting, snake phobias, and psycholinguistics (see Figures 1.13-1.19 in the 1981 *Foundations* volume). Multiplicative integration appears to be an innate mode of stimulus integration.

Averaging Law

The averaging law gives the integrated response as a weighted average of stimulus y-values where *weight* represents importance, distinct from polarity *value* . With *equal weighting* of stimuli within each separate variable, the averaging law obeys the parallelism theorem.

But with unequal weights, the integration is nonlinear and this integration graph will be nonparallel. This was a blessing in disguise. One advantage is that it allows true measurement of *importance* , separate from polarity *value* (a widely popular pitfall). The negativity effect — greater importance of more negative information — was discovered in this way.

Unified Science of Psychology

Many experiments by many investigators have verified the three integration laws in Europe, Latin America, the near East, Africa, and Taiwan. Certain obstacles arose but all were neatly overcome (see *Twelve theoretical issues* , Chapter 3 in Anderson, 2008).

The three integration laws have been established in most areas of human psychology: person cognition, social attitudes, moral judgment, emotion, legal psychology, judgment–decision, psycholinguistics, learning/memory, psychophysics, child development, and others. These same three mathematical laws hold for different persons with due allowance for different personal values — a fundamental capability for psychological science.

This brief overview of Information Integration Theory gives essential ideas. The wide success of the integration laws provides a foundation for unification of psychology as science.

I wish to express my deepest appreciation to my fellow workers in many nations who have done so much dedicated work on problems of information integration. A 4-page listing is given in the *Dedication* in Anderson (2015).

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Appendix A

Functional Rating

The method of functional rating consists of two simple training procedures. First is the use of end anchors, stimuli a little below or above the experimental stimuli. These are ordinarily given with the instruction, “These are the lowest (highest) of the stimuli you will judge; rate them at the endpoints of the rating scale.” This removes the endpoint bias from the experimental stimuli. Second is preliminary practice with the experimental stimuli. This firms up the use of the rating scale.

A graphical rating scale is preferred, although 0-10 and 1-20 numerical scales have been satisfactory. Graphic line-mark response has been used with children as young as 3½ years of age and with illiterate African farmers.

The linearity of the rating scale is thought to derive from accurate action in local space.

Notes

***** Reflection paper.

Additional information

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