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Foundations of Cognitive Theory: A Multidimensional Model of the Message–Attitude–Behavior Relationship

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> By the aid of language different individuals can, to a certain extent, compare their experiences. Then it turns out that certain sense perceptions of different individuals correspond to each other, while for other sense perceptions no such correspondence can be established. We are accustomed to regard as real those sense perceptions which are common to different individuals, and which therefore are, in a measure, impersonal. . . . The only justification for our concepts and system of concepts is that they serve to represent the complex of our experiences: beyond this they have no legitimacy [A. Einstein, *The meaning of relativity* (5th ed). Princeton, N.J.: Princeton University Press, 1956. Pp. 1–2].

A fundamental insight of modern communication theory is that we do not view "reality" except through the mediation of our system of concepts. The interaction of "reality" and our concepts makes up "experience." The goal of science is to render "experience" as orderly, informative, and predictable as possible and it does this by modifying the set of symbols by which experience is represented.

In the absence of concepts, there is no experience at all—at least no experience we can remember from moment to moment. When concepts have been ill chosen, the resulting experiences will be inconsistent and unpredictable. Depending on the inappropriateness, this confusion may range from minor to chaotic.

It follows that behavior as a "reality" has no meaning, and that the meaning of behavior as an "experience" is dependent on the concepts by which it is defined. With little modification, the concept of behavior as it is understood by communication scientists (and the concept "attitude" which is derived from it) comes to us from Aristotle. In virtually every branch of science except com-

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munication and the social sciences, scientists have found Aristotelian concepts incompatible with the symbol system we call "science" and have replaced them with new concepts drawn from Galileo, Newton, Gauss, Einstein, and others.

In this chapter, a non-Aristotelian theory of behavior, based on the works of these thinkers will be presented. Among its advantages will be found (*a*) an increased level of predictability for any behavior; (*b*) a logically self-consistent theory that is also consistent with contemporary physical theory; and (*c*) a relatively well-developed engineering capability.

Behavior, Attitude, and Entelechy

As noted elsewhere (Woelfel, 1977), the structure of Greek thought was heavily categorical, and the notion of the continuum was not well developed. This led to particular difficulties in describing (even prior to explaining) motion or change of any sort. Aristotle's definition of motion, in fact, considers it to be an intermediate semireal state between two "actual" states of being (rather than a quantum physics of subatomic particles, Aristotle describes every entity in experience as a quantum). In Aristotle's view, every body "jumps" from here to there across a semireal state of not actually being anywhere.

Aristotle's thought was not only categorical, but also teleogical. Every object (not only living objects) moved only insofar as it "intended" to be in the place to which it moved. Intention pervaded Aristotle's universe, living and nonliving. It is important to understand that it is not the case that Aristotle generalized his experience of human intention to intentionality for all other things; rather the opposite is true. Aristotle's concept of purpose was developed for nonliving material bodies and applied to human activity subsequently. Aristotle's belief that humans act for ends follows from his belief that the universe acts for ends, and not conversely.

Contemporary attitude theory continues to cling to this Aristotelian model of human activity even though the same model has been found to fail for every other domain of experience to which it has been applied. Behaviors are almost universally conceived of and operationalized as discrete acts, undertaken due to some "purpose" or in order to satisfy some goal, gain a reward, or avoid a punishment (these intentions or predispositions are "attitudes"). What's more, this retention of the Aristotelian theory of human activity is despite consistent, clear, and long-standing failure of the theory in virtually any of its manifest forms to fit observations to even the most generous tolerances. By the late nineteenth and early twentieth century, the deviation of this model from experience was apparent, and, for example, Max Weber posited an Aristotelian rational model for human behavior, but acknowledged its value only as an "ideal type" from which everyday behavior should be expected to deviate (Weber, 1949). Historically, the development of twentieth century social science gave rise to an intensified study of the Aristotelian model, although, to be sure, most social scientists would not have been aware of their debt to Aristotle. The introduction of mathematics into social science in the early decades of this century led to complicated models of internal psychological attitude structures, and the development of the much simpler Likert-type scale and later the very similar semantic differential-type scale led to widespread quantitative studies of human attitudes and their relationship to behavior. The development of the high speed computer, coupled with widespread availability of prepackaged ANOVA (analysis of variance) software during the post war period led to a relatively profuse outburst of what has come to be viewed as the classical model of attitude research: a series of affective orientations toward some attitude object measured by Likert-type or semantic differential-type scales, random assignment of subjects to a message-like treatment, followed by ANOVA checks of the statistical significance of effects. Several dozen such studies have been reported in communication journals, and hundreds may be found in psychology journals.

In spite of the early enthusiasm such studies generated, very little solid theoretical advancement paralleled these researches, and by the early 1970s, such studies reported in the literature had dwindled to only a trickle. The manifest reasons for this disillusionment have been threefold. First, affective conceptions of attitude, that is, measures of the degree to which persons like or favor an attitude object, or perceive likely advantages to accrue to them from the performance of some act, have been very disappointing predictors of later observed behaviors. This has been true virtually regardless of the type of scale employed in their measurement or the type of statistical analysis employed in arraying the data. Second, attitude-change studies have produced a bewildering array of apparently contradictory effects, such as direct changes monotonically related to the change message, nonlinear relations between change stimulus and measured attitude change, delayed changes ("sleeper effect") and even nonmonotone effects ("boomerang effects"). Not only have these changes been widely varied, but seldom is the amount of variance in the change scores explained by the message treatments larger than a few percentage points. Third, and following quite directly from the first two reasons, few efficient or powerful engineering applications have followed from this work. Whereas applications of social science in general have grown rapidly in volume and precision, there is little direct evidence that attitude theory as such has added much additional help to aid in the solution of pervasive and important human problems.

In retrospect, it is easy enough to see that the "classical" approach to the message–attitude–behavior relationship suffers from important methodological problems. First, the universal application of category-type scaling has dramatically restricted the precision of measurement in such studies, thus reducing the amount of reliable variance in attitudes detected in a typical study. This led to a widespread belief that attitudes are hard to change, when in fact only relatively large change could be detected with the imprecise measures used.

Second, the heavy reliance on the ANOVA design led to a strong tendency to establish only whether or not any variance at all is accounted for by the manipulations, rather than to note that the absolute magnitudes of explained variance have been almost universally negligible. This in turn has often led investigators to conclude that theories have been supported because statistically significant effects have been noted, when quantitative evaluations would have led to more disappointing conclusions. Furthermore, in cases where theories have been rejected, the ANOVA design leaves little guidance as to how or in what directions theory must be modified to produce more acceptable results.

Most importantly, such methodological insufficiencies may have led researchers away from a much more important conclusion, that is, that the underlying model of discrete jumps from one qualitative state of behavior to another discrete state of behavior in response to internal affective orientations to attitude objects may itself be false, or at best applicable to a very small range of human activity.

At the same time, a viable alternative formulation of the message–attitude–behavior relationship was being developed particularly by the philosopher George Herbert Mead (1934) and his followers, most of whom were sociologists. Mead (who, as a philosopher, was a specialist in the study of Aristotle), although concerned with discrete acts, explicitly directed attention toward behavior as a continuing process, rather than as a series of discrete acts. He frequently used the word "ongoing" to describe human activity. To be sure, Mead considered human behavior to exhibit a deliberate, purposeful aspect, but this he considered to emerge only at junctures where the ongoing activity had been interrupted. By far the larger part of human activity consisted of carrying out relatively standardized processes appropriate to a role or set of roles, which together constituted an organized self. An attitude within this model consists of the global relationship of the individual to an object or set of objects, including but not restricted to an affective component. While the subjective utility of adopting an attitude or role was a factor in Mead's account of an actor's assimilation of an attitude or role into the self, by far the larger part of the basis for adoption of an attitude or role was the consistent and repeated definition of those attitudes or roles as consistent with the individual's self by the set of "others" with whom the individual communicated or "interacted."

Insofar as the position of an actor in his or her environment is continually changing due to the ongoing process of activity, attitudes in Mead's theory are in continual flux. Insofar as the behaviors (and situations within which behaviors are enacted) are organized, and insofar as the definitions of the self offered by others around the individual are consistent over time, the self and its constituent attitudes exhibit organization and stability. Depending on which of these two aspects of Mead's thinking they emphasized, two schools of thought emerged from Mead's work. The first, primarily developed by Mead's student Herbert Blumer (1969) emphasized the spontaneity and evaescence of attitudes and the self. This school never developed a quantitative research focus, although it has led to much insightful analysis of human interaction.

A second group, following from the work of other students of Mead, Manford Kuhn and Alfred Lindesmith, and from Lindesmith's student Anselm Strauss (Lindesmith & Strauss, 1956), emphasized the more stable aspects of attitudes and the self. This work was given an initial quantitative form by sociologists for the most part, particularly by Sewell and Haller. Important clarifications of the theory were offered by Mills (1940), who conceived of acts as if they were words, and likened the decision to perform an act to the "decision" to apply an appropriate word in a given linguistic context. A "motive" for Mills was less a driving force toward action than a justification for an action which one has learned as appropriate for a given behavioral context. This view was made more explicit by Nelson Foote (1951), and reached a particularly clear form in the work of Edwin Lemert (1951).

Lemert suggested that individuals, particularly children, often exhibit relatively random and unorganized behaviors, some of which are deviant according to either statistical or moral norms. When observers take note of such behavior and offer consistent role definitions of the individual on the basis of these observations (labeling), the individual may adopt these definitions of self, ascribe the labeled role to themselves, and therefore enact behaviors conceived to be appropriate to the role regardless of their perceived personal utility.

Sewell, Haller, and Portes (1969) extended these notions away from deviant acts and roles, and posed a theory suggesting that the consistent definitions of "significant others" might lead adolescent youth to designate a specific level of educational attainment as appropriate to themselves, and consequently seek an education within this band. Their empirical research was able to explain fully 50% of the variance in the decision of high school seniors to attend college. Later, Haller and the present author (1971) showed that the averaged educational and status expectations of a set of "significant others" for a sample of high school students accounted for about 50% of the variance in the educational and occupational aspirations of those children. (These aspirations are clearly the kind of long-range stable attitudes that lend themselves well to empirical research in the field.)

The Significant Other Project (Woelfel and Haller, 1971) was significant in another unexpected respect. By 1967, the most formal statements of self-theory, in spite of their verbal emphasis on process, were still categorical in form (Kinch, 1963; Woelfel, 1967). Activities, like other objects, were thought to be defined by placing them into categories, and the self was similarly thought to be defined by being placed into categories. (Bruner, 1958; Woelfel, 1967). The resulting relationship between object and self (the attitude) was then either consistent (this is the type of behavior a person like myself might perform) or inconsistent (this is not the type of behavior a person like myself might perform). This categorical form of the theory resisted precise measurement, made mathematization of the theory cumbersome, and led to important theoretical intractability, particularly when dealing with the problem of multiple and disparate sources of influence (such as significant others). If all of a person's significant others held consistent expectations for his or her behavior, prediction of subsequent activity was simple, but how an individual might behave when faced with multiple and disparate expectations remained problematic. In fact, the problem of which behavior to choose reduced to the question of which influence source to accept, which is really the same question pushed back one stage (this same question provided the impetus for the long-term interest of communication scientists in source credibility).

The significant-other project led out of this infinite regress in a purely accidental way. As it turned out, both attitudes measured in that study were attitudes toward levels of attainment (i.e., the level of education students hoped to attain and the level of occupational prestige to which they aspired). Each of the expectations of each of the individual's significant others was thus represented by a value on a continuum. For lack of a more sophisticated alternative suggested by theory, these multiple expectation levels were simply averaged to yield an average level of expected attainment. Surprisingly, this variable alone accounted for more than half the variance in the students' own attitudes. This was higher than other attitude researches had attained, even using extensive multivariate models, by a wide margin.

Careful scrutiny of the logic of averaging then led investigators to realize the potential of the theory implicit in this operation, since it turns out that the average of any set of diverse expectations represents a least-squares balance point at which resulting stresses ought to be at a minimum. Such a theory (sometimes called—somewhat unfortunately, perhaps—Linear Force Aggregation Theory) had many desirable features. First, it lent itself very well to mathematical statement, since the equation for attitude change reduced simply to the expression

$$A_n = (A_0 N_0 + I N_1)/(N_0 + N_1) \tag{1}$$

where A_n = The new attitude
A_0 = The old attitude
N_0 = The number of messages (amount of information) out of which the old attitude was formed
I = The average value of the new information received
N_1 = The number of messages in the new information.

Second, the theory predicted unambiguously that the stability of any attitude would be proportional to the amount of information (number of messages) out of which it had been formed. Subsequent research, particularly by Saltiel (Saltiel & Woelfel, 1975) and by Danes, Hunter, and Woelfel (1978) have been strongly supportive of this notion over alternative plausible formulations. Third, the theory could be shown to be identical in form to classical

Newtonian theory. The possibility of a unified theory encompassing conceptions not only of social and psychological changes but physical motion as well has been very exciting. Consider, for example, the implications of the fact that equations from Newton's theory predict human attitude change and human behaviors better than any theory specifically developed to deal with human phenomena by a wide margin (to be sure, this notion still constitutes a formidable barrier to the theory's acceptance by social scientists to whom the fundamental difference of humans from all other aspects of nature remains a basic philosophical and even religious belief).

In spite of the moral outrage caused some workers by a "physical" theory of human behavior, the predictive record of the theory even in this early formulation has been extraordinary. In a previously unreported study, Woelfel and Hernandez (1970) were able to account for 89% of the variance in rate of marijuana smoking in four separate random samples of 341 university students from two countries. This study is particularly interesting because it provides a direct contrast between affective and cognitive attitude theories. The traditionally conceived attitude, measured by the item "What is your attitude toward marijuana?" followed by five response alternatives ranging from very beneficial to very harmful, explained less than 5% of the variance in self-reported rate of use, while the self-concept item "To what extent do you consider yourself the type of person who might smoke marijuana?" followed by five response alternatives accounted for over 80% of the variance in self-reported behavior alone. While one might be tempted to think that this measure is a consequence of one's observation of one's own smoking behavior rather than a cause, the fact that over 70% of the variance in that item itself can be accounted for by the weighted average of expectations for the individual of his or her friends contradicts such a simplistic explanation.

Mettlin (1973) used an identical model to account for about as much variance in cigarette smoking among adults. In a widely different context, the same model did approximately as well in explaining both the formation of attitudes and subsequent behaviors toward French Canadian Separatism among a sample of adult residents of Montreal, Quebec, Canada. (Woelfel, Woelfel, Gillam, & McPhail 1974). Although other examples could be cited, it should suffice to point out that, even in this early form, the theory has never failed a research test, and in fact no alternative theory of which we are aware has accounted for as much variance as has this theory in as wide a variety of contexts.

In spite of these early successes, the theory in this form exhibited important deficiencies. First among these was that the theory did not tie itself unambiguously to a consistent measurement system, but rather relied on the imprecise category-type scales like the Likert-type and semantic differential-type scales then in current vogue among attitude researchers. Researchers have long been aware that the use of such pseudoordinal scaling methods was far less desirable than the use of ratio-type scaling, but few researchers, with the important exception of Stevens (1951) and his student Hamblin (1974), had any real idea of how to move to the level of ratio scaling. Secondly, the theory was restricted to applications in those areas where dependent attitudes and behaviors could be quantified as rates (like rate of cigarette smoking) or pseudorates (like level of occupational prestige). This is not to say that predictions the theory made about the adoption or nonadoption of discrete behaviors were false, but rather that the theory could make no such predictions, since no method for averaging discrete expectations was known. Thus, for example, if one's mother wanted one to be a doctor and one's father wanted him or her to be a lawyer, the theory must predict that he or she would select an occupation "between" these two expectations, but it was not clear what "between" might mean in this context.

Categories and Continua

Of course one does not choose between "doctor" and "lawyer", but rather between one's experience of doctor and lawyer. This experience of doctor or lawyer is an "object" (Blumer, 1966) to the person. An object may be thought of as a category into which a person may or may not fit, and this, of course, is the source of the difficulty. But the object itself may be defined by placing it into still more general categories, such as "occupation," "high-paying," and so forth. Different objects (occupations, in this instance) may be placed into categories on the basis of their similarity in some regard. Similarity (or dissimilarity) however, is not a categorical concept, but rather a continuously variable notion, bounded by identity (no difference) and infinity (infinitely different). This point marks an important interface between the idea of the discrete or categorical and the idea of the continuum, since objects are included into a category when they are "sufficiently" similar to warrant inclusion. In fact the argument can be made that similarity is a prior notion to category, since objects are categorized on the basis of their similarity. The notion of category is, in fact, related to the notions of purpose and interest, since a set of objects may be similar enough to warrant inclusion in the same category for one purpose, yet different enough to fit different categories for other purposes even though their similarity relations remain the same. In such cases, only the purpose or interest changes. Thus if we have a specific ailment, doctors are too different from each other to be included within a single category, but rather a specific doctor is needed, and must be distinguished from all other doctors. Yet if our interest lies in choosing an occupation, all doctors may be safely placed in the category "doctor," even though all the differences among them, of which we were previously aware, still exist. Only the importance of those difference or separation relations for our purposes has changed. Thus, for some purposes, the set of difference relations among a set of objects may be unimportant, and so we may consider the set as a single object, which is itself embedded in a set of difference relations with yet other objects. Each of these may also be subdivided as our need requires, and so on. For our purposes, a set of objects may be considered a single object when the difference relations or separations among its constituent objects are too small to be important for the purpose at hand, even though we understand that the object is not inherently monistic, but has designatable and differentiable internal components.

Our experience consists of such objects, ranging from the smallest objects capable of discrimination from the background of our experience by our sensory apparatus, up to the most global categories. Clearly, no object has existence independent of the human act of categorization. These objects are arbitrarily discrete regions, neighborhoods, or domains of the continuum of experience which are bounded by some interest that makes the neighborhood particularly salient. These neighborhoods or domains are often made to seem even more discrete because they are named or described by recourse to a symbol or set of symbols, such as "Albany" or "happiness," although neither Albany nor happiness have distinct natural boundaries independent of arbitrary human designations. These objects are themselves sufficiently different or far removed from other regions to be designated by different symbols. Objects may then be described as named regions or neighborhoods separated from other such neighborhoods by some distance or dissimilarity. In this sense, it is possible and meaningful to conceive of a region that lies between the region of experience called "doctor" and the region of experience called "lawyer." Overall, therefore, our experience may be thought of as a space within which lie symbols designating regions of our experience which have been salient enough to be designated by symbols. In order to show how such a space may be constructed and calibrated, and to aid in distinguishing it from other spatial renderings of human cognitions like those particularly of Osgood, Suci, and Tannenbaum (1957), it is appropriate to proceed somewhat more formally than previously.

Definitions

We assume that individuals encode observations into symbols, combine and store the symbols in some way, and compare them with other persons and across time by means of language. These processes are cognitive processes. Science, by this definition, is a cognitive process, although a collective cognitive process to be sure. Gauging the state of one's health across the years is also a cognitive process, as is determing one's own political position from day to day. Collective cognitive processes (or cultural processes) are those cognitive processes resulting from the coordinated activity of a system of individual cognitive processes, like science, ensemble music, or election of government officials.

The primary symbol system underlying cognitive processes is assumed to be the vernacular language. Relatively invariant complexes of experiences are symbolized by certain vernacular language words like "red" or "hard" or "disappointed." These several complexes themselves are perceived to differ from each other in some ways; in fact, the minimal comparison between two experiences that can be reported is the dichotomous discrimination of difference versus no difference. The differences or separations among the symbols are considered primitive or fundamental variables in the theory. Any concept in the language has a meaning that is given by its pattern of similarities and differences to the other concepts. Change in these separations over time therefore represents change in meaning or definition of concepts. These changes are cognitive processes.

The Symbol Set

The first step in measurement is the stipulation of a symbol set. We choose the set of positive real numbers (see Suppes and Zinnes, 1963) for several reasons. First, since the set is infinite, there is no minimal interval size as with a finite set, like, for example, the semantic differential 7-interval scale. Moreover, the real number system is systematic, forming new symbols by rules; a very large set of transformations in the set (like addition and multiplicating, for example) are well known, and a very large set of people are already familiar with elements of the real numbers—far more than are familiar with other psychometric devices.

Rules of Correspondence

The second requirement of measurement is the establishment of a clear, consensual, and unambiguous rule for establishing correspondences between observations and symbols. We choose, following Einstein (1961) and others (Campbell, 1928; Ellis; 1966; Hamblin, 1974, Hays, 1967; Krantz, Luce, and Suppes, 1971; Stevens, 1951; Suppes and Zinnes, 1963), a ratio rule. First, an arbitrary element of the set of observations to be measured is designated as a unit standard against which all other observations are compared. As noted earlier, the primitive observations of cognitive processes are the separations among concepts, and one of these separations is chosen as a standard; other separations are compared to this standard as ratios. Formally, the rule is expressed as a conditional statement "if a and b are u units apart, how far apart are x and y?" In the present case, "far apart" is defined to mean "different in meaning" so that increasing numbers represent pairs of concepts of increasingly different meaning. Formally, the rule requires that a pair of concepts S_{ab} whose difference in meaning is perceived to be double that of another pair S_{eb} should be represented by a separation double that of the second pair, or $S_{ab} = 2S_{eb}$. Furthermore, no formal restriction on how small a difference may be reported is established by the scaling procedures: Limitations of precision are given by the observational capabilities of the observer, and not by the scale on which such differences are reported. It is important to understand that the use of a precise scale does itself not guarantee precise measurement, since the actual process by which the scale is employed can add or subtract from precision. Because the length of a bridge, for example, is *reported* in ratio numbers—say, meters—does not guarantee that the measurements have been carefully made. But the use of an imprecise scale—like a semantic differential scale—is sufficient to limit precision of measure.

It is also important to note that this procedure of measuring the dissimilarities in meaning directly is inherently more precise than the indirect procedure recommended by Osgood *et al.* (1957), where the pairwise dissimilarities of any two objects are calculated from their measured dissimilarities from a set of attribute words. Nor is the difference minor. Meyer (1975) shows this with a simple example:

> Suppose one wishes to measure the voltage between two dynodes A and B of a photomultiplier tube.
>
> 1. We may measure $V_A = (2010 \pm 10)$ Volts and $V_B = (1982 \pm 10)$ volts using a voltmeter capable of a relative error $\epsilon \sim 10/2000 = 1/2\%$. The voltage difference $V_A - V_B = 28$ volts with an error of $\epsilon_{(A-B)} = \sqrt{10^2 + 10^2} = 14$ volts yielding $V_A - V_B = 28 \pm 14$ volts. $\epsilon_{(A-B)} = 50\%$
> 2. We may measure the voltage difference directly with a voltmeter good to 10% and get 28 ± 3 volts. It would appear that there is usually a hard way to do business [p. 41].

Note that the use of the indirect procedure increases the error in this simple instance by 500%, even though the measurement instrument employed was 20 times more precise. Communication researchers, like other social scientists, have often been indifferent to precision of measure, and the result often has been that good ideas (like Osgood's notion of semantic space) have failed to yield much more than insights because they are simply too crudely measured to behave lawfully. Although our intentions bear important resemblences to Osgood's, the execution in the present case can be shown to produce results up to several orders of magnitude more precise than are possible by Osgood's methods. Whatever imprecision of measure may exist within this system is not a consequence of the imprecision of the scale on which measurements are reported, and this is a crucial advantage.

Once accomplished, these procedures make possible a mathematically precise definition of the meaning of any concept; since each concept is defined by its relative similarity to all other concepts, any concept C is defined by the $1 \times (k - 1)$ vector of separations from the $k - 1$ other concepts. The interrelationships among any subset of k concepts is similarly given by the $k \times k$ matrix $\bar{\mathbf{S}}$ of separations among the k concepts averaged across members of the culture.

An important notion of interactionist theory is that the self may be an object of the individual's experience in the same way as any other concept may be the object of attention. Furthermore, it is quite explicit in virtually every version of Mead's thinking and that of his followers that the self is defined in terms of its relationship to other objects of experience. It is thus completely

TABLE 3.1
Length of All Self-Concept and DHIA Vectors by Adaptor Categories
(Numbers in Parentheses Are The Percentages of Error for the Value Directly above the Percentage Value)

Sample	Concepts												
	Accurate information	You	Good	Convenient	Keeping records	Culling	Breeding	Measuring production	Necessary	Profit	Inexpensive	Computers	Useful
$N = 22$													
Nonadoptors													
You	54		39	54	49	51	49	57	40	55	70	148	43
Error	(17)		(16)	(13)	(19)	(16)	(17)	(18)	(27)	(18)	(22)	(18)	(32)
DHIA	91	181	114	107	81	91	109	117	142	141	153	137	107
Error	(35)	(20)	(31)	(25)	(37)	(37)	(46)	(45)	(39)	(40)	(36)	(41)	(49)
$N = 21$													
Discontinuers													
You	62		41	53	45	32	37	73	45	37	46	163	46
Error	(27)		(20)	(17)	(18)	(21)	(21)	(27)	(44)	(25)	(28)	(32)	(36)
DHIA	93	138	100	121	93	101	76	63	111	100	109	79	79
Error	(38)	(26)	(39)	(26)	(62)	(56)	(38)	(46)	(27)	(31)	(28)	(47)	(40)
$N = 81$													
Adoptors													
You	38		40	50	45	41	34	30	43	46	52	89	35
Error	(10)		(11)	(10)	(15)	(11)	(12)	(19)	(23)	(13)	(13)	(15)	(11)
DHIA	30	22	30	35	18	24	27	20	26	28	46	36	21
Error	(14)	(17)	(14)	(13)	(21)	(17)	(20)	(27)	(22)	(17)	(16)	(26)	(24)

appropriate to define the self by including it among the set of objects in the pair comparisons. Thus the self may be defined as well by its $1 \times (k - 1)$ vector of separations from the $k - 1$ other concepts. For convenience it will be useful to define each of these pairwise dissimlarities, as perceived either by an individual or by a set of individuals as a *belief.* Furthermore, since Mead defines attitudes as the orientation or relationship of the self to some object or set of objects, it is consistent with his position to define *attitude* as a belief about the self, that is, the measured separation between the self and any object or set of objects. All attitudes are beliefs, therefore, but the converse is not true. Within the present model, therefore, attitudes are primarily cognitive structures that may or may not include an affective component.

Since, following Blumer, an object is "anthing which may be designated or referred to [Blumer, 1967]," behaviors or actions may be arrayed as objects in this space. It is therefore possible and sensible to estimate persons' attitudes toward behaviors as distance or separations between the self and those behaviors. These global relationships are entirely consistent with virtually all interactionist writers' views, since they have meaning only within a complete context within which both object and self are defined relative to all other relevent objects.

Conceived of and measured in this way, attitude bears some relationship to more conventionally measured attitudes. Danes and Woelfel (1976), for example, found the correlation between distance from the self to political figures to correlate with conventional favorability measures for the same figures about .9. The same pattern has been repeated in other studies. Important exceptions exist, however. Green, Maheshwari, and Rao (1969) did not find substantial correlations between distances from self and favorability, but many of their objects were "big ticket" items out of economic reach. This indicates people can place an object far from themselves even if they are strongly in favor of it if, on other grounds (such as price) it is "out of reach." In fact, there is substantial evidence from many sources that attitude conceived and measured as distance from the self is a much better predictor of behavior than any other formulation yet devised. Table 3.1, for example, is typical of the relation between distance from self and behavior. It shows the distances among the self and a set of concepts relative to a dairy-herd testing service of three groups, those who have adopted the testing service, those who have not adopted, and those who have discontinued the service. Note particularly the distance between self and the testing service (DHIA) is 181 for nonadopters, 138 for discontinuers, and only 30 for adopters.

The Geometry of Separation

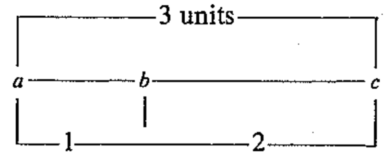
The concept of a geometry of separation capitalizes on the recognition that physical distance is viewed as a special case of separation in general, and thus is isomorphic to conceptual separation in formal structure. Therefore, conceptual separations may be presented in a geometrical format analogous to the depiction of physical distance; the separations in the matrix $\bar{\mathbf{S}}$ may be arrayed in a geometrical pattern. Consider the matrix:

$$\bar{\mathbf{S}} = \begin{array}{c} \\ a \\ b \\ c \end{array} \!\!\begin{array}{c} \begin{array}{ccc} a & b & c \end{array} \\ \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \end{array}$$

Here, since $\bar{\mathbf{S}}_{ab} = \bar{\mathbf{S}}_{ac} = \bar{\mathbf{S}}_{bc} = 0$, the three concepts lie on a point in a zero (0) dimensional space. In the matrix:

$$\begin{array}{c} \\ a \\ b \\ c \end{array} \!\!\begin{array}{c} \begin{array}{ccc} a & b & c \end{array} \\ \begin{pmatrix} 0 & 1 & 3 \\ 1 & 0 & 2 \\ 3 & 2 & 0 \end{pmatrix} \end{array}$$

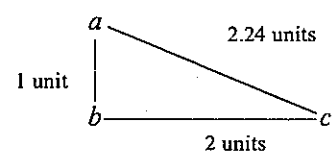
the separations form a line segment in a one-dimensional space which may be geometrically arrayed as the following pattern:



and the matrix:

$$\begin{array}{cccc} & a & b & c \\ a & 0 & 1 & 2.24 \\ b & 1 & 0 & 2 \\ c & 2.24 & 2 & 0 \end{array}$$

represents a triangle in a two-dimensional Euclidean space.



And finally consider the matrix $\bar{\mathbf{S}}$ that extends outside the real number domain:

$$\bar{\mathbf{S}} = \begin{array}{c} \\ a \\ b \\ c \end{array} \!\!\begin{array}{c} \begin{array}{ccc} a & b & c \end{array} \\ \begin{pmatrix} 0 & 1 & 4 \\ 1 & 0 & 2 \\ 4 & 2 & 0 \end{pmatrix} \end{array}$$

This geometrical pattern represents a complex, non-Euclidean space of 2 dimensions; one real and one imaginary dimension. The translation of conceptual separations into a geometrical configuration will produce a spatial configuration of r dimensions, where r is always one or more fewer than the number (k) of conceptions judged ($r \leq k - 1$).

Transformation Rules

Among the most important transformation rules are those describing the symbolic operations by which observations are transformed to correspondence across observers and over time, since these are the transformations by which information is conveyed among individuals. Since the primitive data of the theory consist of the matrix of reported separations **S** or $\bar{\mathbf{S}}$, we will be particularly interested in transformation rules that preserve these separations. Restricting ourselves to transformations that preserve the raw separations guarantees that the data are never distorted. In this way, data provided by measurements may never be "tampered with" and remain the final arbiter of theory.

Frame of Reference. Once the observations have been encoded into the symbols of the theory, we may begin to compare them across observers and over time to discover invariances. The first step in this comparison process is to transform those observations into a convenient frame of reference (Goffman, 1974; Halliday & Resnick, 1966). Although the concept of reference frame has occupied an important place in virtually every social science (and in physics), it has generally resisted precise quantitative treatment in the social sciences. Since this theory is founded on a fundamental variable (separation), which is formally homomorphic with physical distances, it is possible to make use of mathematical procedures developed to establish physical reference systems to generate reference frames for cognitive processes. The procedures used here were developed by Young and Householder (1938) and Torgerson (1958) under the name *metric multidimensional scaling.* First, the matrix of separations **S** is centered and premultiplied by its transpose to give the scalar product matrix **B**

$$b_{ij} = \frac{1}{2}\left(\frac{1}{k}\sum_{i}^{k} d_{ij}^2 + \frac{1}{k}\sum_{j}^{k} d_{ij}^2 - \frac{1}{k^2}\sum_{i}^{k}\sum_{j}^{k} d_{ij}^2 - d_{ij}^2\right) \tag{2}$$

which is then reduced by the Jacobi procedure[1] to an orthogonal matrix of Eigenvectors **R**. The matrix **R** represents a rectilinear coordinate system upon which the concepts are projected as vectors. For k concepts, the matrix **R** is always $k \times r$ where $r \leq k - 1$. Each column vector of **R** represents one dimension of the space and is orthogonal to all other columns. Each row of **R** represents the position vector of the concept in the space (Davis & Snider, 1975).

Although it makes little difference for the elementary presentation in this

[1] This procedure is formally identical to a complete principle-components factor analysis of the **B** matrix. It differs from typical factor-analytic procedures in that (a) the input matrix consists of ratio-scaled scalar products rather than correlations; and (b) all the factors are extracted rather than just a subset. This means that the original distances may be regenerated from **R** with no error.

chapter, advanced work within this non-Euclidean space is greatly simplified by adopting the convectional tensor notation for these vectors. (McConnel, 1933). Within this notation, any concept is represented by the first rank tensor $\mathbf{R}^{\mu}_{(\alpha)}$ where the α in parentheses represents the αth concept. (It is placed in parentheses to indicate that it is not a tensor index, but rather simply a designation of which tensor we are discussing. The superscript μ ranges from one to r, where r is the number of dimensions in the space and refers to the coordinate value of the tensor on the μth dimension. In this notation, the self is represented by the tensor $\mathbf{R}^{\mu}_{(\alpha)}$,

No information is lost by this transformation, nor of course, is any created. Since the set of reference vectors upon which the concepts are now projected is orthonormal, however, mathematical treatment of processes among the concepts is substantially simplified, since vector equations defined on rectilinear coordinates take on a very convenient algebraic form.

This is in marked distinction to the transformation by which Osgood converts measured dissimilarities into "semantic space." In Osgood's procedure, the covariance matrix derived from the intitial measurements is first standardized, then factored. The resulting factors serve as orthogonal vectors on which each of the concepts is projected. Due to the standardization, however, these eigenvectors are not unit vectors; rather each concept's position vector has been unitized, so that the position vector of each concept in the space is one unit in length regardless of its length in the raw measures. We have already remarked that the indirect measurement procedure used by Osgood costs a great deal in precision, as does the use of the categorical semantic differential-type scale, and that together, these errors in judgment may cost as much as several orders of magnitude of precision. Compared to the distortions resulting from this standardization procedure, however, these earlier problems are small. As shown elsewhere (Woelfel & Danes, 1979) this procedure, when applied to a map of the United States cities, produces distortions in excess of *several thousand kilometers* in the position of many of the cities, and results in absurdities such as the location of Miami several hundred kilometers north of Chicago. The result of these distortions is that the distances among concepts in Osgood's semantic space are virtually randomly related to their distances as measured (the skeptical reader is invited to test these conclusions with data of a known configuration, such as physical distances or the arrangement of objects on his or her desk). In the Galileo™ type procedures described here, however, no information is lost and no distortions incurred whatever, and measured distances may be reproduced to within computational rounding error, which, at default values in the Galileo™ computer program is preset at .001%. Thus whereas the semantic space of Osgood provided an insightful and ingenious way to array concepts, from a computational point of view, it is sufficiently imprecise to be virtually useless for the investigation of attitude changes. This very imprecision, in fact, plays an important role in Osgood's finding of virtually no variation in semantic space even across major cultural boundaries, since the space is too inaccurate to note any but the most overwhelming differences.

While this rectilinear coordinate system shares important characteristics with the familiar 3-dimensional rectilinear coordinate system of classical mechanics, it differs in two important ways, both consequences of the empirically derived structure of the concepts measured to date. First, the rank or dimensionality of the space is higher than 3, although the exact rank varies across concept domains and across time, as well as across individuals. Second, the space is almost always found to be non-Euclidean. In spatial terms, non-Euclidean spaces are warped or bent; in cognitive terms, non-Euclidean separation patterns represent inconsistencies among conceptions.

Non-Euclidean geometric structure is represented in the Galileo configuration by negative characteristics roots (eigenvalues) in the matrix; negative eigenvalues indicate imaginary components of the eigenvectors corresponding to these roots, since the eigenvalue is the sum of the squared components, as

$$\lambda_{\mu} = \sum_{\alpha}^{k} (\mathbf{R}^{\mu}_{(\alpha)})^2 \tag{3}$$

While these imaginary components and negative roots were intially considered by many psychometricians to be artifactual or indications of error, their consistent recurrence, stability over time, and generally lawful behavior (e.g., they are generally larger in absolute magnitude for domains not clearly understood by or unfamiliar to respondents) seem to indicate that they should not be disregarded. Furthermore, they add no essential mathematical difficulties as long as care is taken to preserve their signs during numerical computations.

Cross-Observer Transformations

For any observer, these operations performed across k concepts will yield the $k \times r$ matrix $\mathbf{R}$ representing a (non-Euclidean) rectilinear coordinate system upon which are projected k positions vectors $\mathbf{R}^{\mu}_{(\alpha)}, \mathbf{R}^{\mu}_{(\beta)}, \ldots, \mathbf{R}^{\mu}_{(k)}$. The end points of these vectors, as has been shown, constitute a geometric pattern that corresponds to the interrelations among the concepts as seen by the ith individual.

Comparisons of the observations of two or more observers, once those observations have been encoded into this system, constitutes a two-step procedure. First, a transformation on one or both of the reference frames must be identified, which minimizes the discrepancy among the two or more spaces, while preserving the separations within each. Once this has been accomplished, the resulting matrices simply may be compared by subtraction. These distance-preserving transformations are called rigid motions, and consist of rotations and translations on the coordinates.

Translations within the Galileo reference frame are straightforward extensions of translations in the 3-space common to ordinary physical conception. First, some arbitrary point $\mathbf{R}^{\mu}_{(p)}$ is chosen, and its position vector is subtracted from the position vectors of all concepts in the space such that

$$\hat{\mathbf{R}}^{\mu}_{(\alpha)} = \mathbf{R}^{\mu}_{(\alpha)} - \mathbf{R}^{\alpha}_{(p)} \tag{4}$$

Since $\mathbf{R}^{\mu}_{(p)} - \mathbf{R}^{\mu}_{(p)} = 0$ (the null vector) this has the effect of placing the pth point on the origin of the reference frame. This procedure is carried out for the reference frame of each person in the comparison, so that the reference frames of each observer are centered on the same point.

Next, the two coordinate frames are rigidly rotated to a least-squares best fit on each other. This rotation is accomplished by successive pairwise infinitesimal rotations of the eigenvectors until the total squared distance of concepts from their counterparts across observers is minimized (Woelfel *et al.*, 1975). Since we are concerned only with those transformations that preserve the original separations, rotations must be carried out separately for the positive eigenvectors and the negative eigenvectors. This is required since distance is not invariant under rotation of complex numbers, and is permitted, since each of the positive eigenvectors is orthogonal to each of the negative eigenvectors. (Woelfel, Holmes, & Kincaid, 1979).

Once these operations have been carried out for any two persons, they yield the transformed matrices $\mathbf{R}_i$ and $\mathbf{R}_j$ for the ith and jth individuals. Comparison of space is now given straightforwardly by the subtraction

$$\hat{\mathbf{R}}_i - \hat{\mathbf{R}}_j = \Delta\mathbf{R} \tag{5}$$

where the matrix $\Delta\mathbf{R}$ represents the difference between the cognitive structures of the ith and jth individuals. Any row $\Delta\mathbf{R}^{\mu}_{(\alpha)}$ of $\Delta\mathbf{R}$ represents the difference between the definition of the αth concept as seen by the ith and jth persons within a now common reference frame.[2] The length $|\mathbf{R}^{\mu}_{(\alpha)}|$ of any row vector of $\Delta\mathbf{R}$ represents the distance between or difference in meaning between the same word as used by the ith and jth person.

Over-Time Transformations

The description of process in the Galileo framework essentially involves the comparison of a time-ordered series of individual coordinate frames $\mathbf{R}_{t0}$, $\mathbf{R}_{t1}, \ldots, \mathbf{R}_{tn}$ or aggregate coordinate frames $\bar{\mathbf{R}}_{t0}, \bar{\mathbf{R}}_{t1}, \ldots, \bar{\mathbf{R}}_{tn}$. As is well known in physical science, there exists no single "privileged" coordinate system against

[2] For an interesting alternative procedure for the comparison of individual cognitive structures, see Marlier, 1974. Marlier's procedure involves the projection of the individual cognitive spaces of a series of individuals into an aggregate space based on the average separation matrix $\mathbf{S}$, after which individual differences can be estimated by linear regression techniques. Marlier is able to account for over 72% of the differences in individual perceptions with this model.

which absolute changes may be measured, and the situation is no different in cognitive space. As is clear from the nature of the procedure by which the Galileo coordinate frames are constructed, the orientations of the eigenvectors of any time frame are functions of the state of the configuration at that time, and therefore any change in the configuration over time will result in an artifactual reorientation of the reference axes (eigenvectors). This is equivalent to comparing motions across reference frames which may be "tumbling" (i.e., in nonuniform rotation and translation) relative to each other. The first step in making comparisons, therefore, is a series of rotations and translations as described earlier to bring the time-series of coordinate systems into best-fit with each other (Woelfel *et al.*, 1975). Several such procedures are possible. First, if no information other than that contained within the matrices at each time period is available, rotation and translation to simple least-squares best-fit across the time-series is appropriate. If additional constraints can be determined on other grounds (as, for example, might be the case if the observer were to know that some of the concepts had been implicated in messages across a time interval and others had not) some of the concepts might be differentially weighted into the minimization procedure or even left as free parameters, as is described in detail elsewhere (Woelfel *et al.*, 1979). One such strategy might be to translate the origin of the reference frame onto the concept of self (the "me") at each time interval, then rotate the spaces serially to a least-squares best-fit on those concepts the individual herself or himself reports as relatively unchanging across the time interval measured. For an equivalent cultural solution, the aggregate "me" might be set at the origin of the collective space, and least-squares criteria applied to those concepts collectively judged stable over time. The resulting process would represent the individual cognitive processes or collective cultural processes as seen respectively by the individual, or by the culture as a whole. What is most important, however, is the understanding that the description of the processes—and hence the "laws of nature"—within the spaces will be altered by different choices of a rotation scheme, and that there exists no "correct" choice. Once a choice has been made, however, processes will be wholly determined by observations (data) within that framework, and will be the same for all observers who utilize the same rotation scheme. *Within this consensus*, it makes sense to say the processes are observed and laws discovered; the consensus itself, however, is created by the observers and not discovered.

Velocity and Acceleration. Once a stable reference frame has been defined (by whatever means), it becomes a simple matter to describe cognitive processes relative to that frame. At any instant, the definition of a concept is given by its location in the reference frame, which in turn is given by its position vector $\mathbf{R}^{\mu}_{(\alpha)}$. Changes in the meaning of any concept will be given by a *change* in location, or a change in the position vector $\Delta\mathbf{R}^{\mu}_{(\alpha)}$. For any interval of time Δt, therefore, the average rate of change of meaning or average velocity is given by $\Delta\mathbf{R}^{\mu}_{(\alpha)}\ \Delta t$. At any instant in time, this velocity will be given by the derivative $V_t = d\mathbf{R}^{\mu}_{(\alpha)}/dt$. In the space of reference, R is given by its r components $R^{\mu}_{(\alpha)}$.

Since the reference vectors are orthogonal in the Galileo reference frame, the partial derivatives are linearly additive, giving

$$V_t = \sum_{i=1}^{r} dR^{\mu}_{(\alpha)}/dt \tag{6}$$

Equation (6) represents the direction and rate at which a given concept is changing in meaning at an instant t. This rate itself may change over time, and this change in the rate of change is formally an acceleration, which is given by the second derivative

$$a_t = d^2R^{\mu}_{(\alpha)}/dt^2. \tag{7}$$

It is these accelerations that require explanation and so they are of particular importance. Nevertheless it is important to understand that the accelerations will turn out differently if different rotation and translation strategies are employed earlier in the analysis, and so, also, will the laws that account for them. This suggests an additional strategy for such transformation decision: For completely practical reasons, those distance-preserving transformations should be chosen which produce the simplest laws of motion within the cognitive reference frame.

Explanations of Cognitive Processes

The equations developed in the previous section are powerful descriptive tools, and many even more powerful descriptive equations can be found in physics, engineering, and mathematics books dealing with mechanics and vector and tensor analysis, as long as one is careful to generalize those equations to r dimensions, while paying careful attention to the signs of the roots corresponding to the dimensions. The implication that equations for cognitive processes may be found in physics books has generally been viewed with a combination of suspicion and alarm by social scientists on the ground that psychological or cultural processes are not analogous to physical processes. These arguments are not germane here, since the equations listed do not predict or require any specific processes in the cognitive reference frames, but simply describe those processes whatever they may be. That such equations can describe processes within this system is not an empirical question, but simply a formal consequence of the arbitrary distance rule chosen. The question at issue is not whether equations which describe the processes observed in the system can be found, but rather whether those equations, once found, are sufficiently simple to allow predictability greater than that obtainable with ordinary language. To the extent that such equations yield patterned regularities, they will yield such increased predictive power. As we suggested earlier, such patterned regularities, or invariances, once named, constitute scientific laws valid within the reference system.

Simple Messages

To illustrate what such laws might look like in this system, consider the following example:

Figure 3.1 represents the first principal plane of the space representing (hypothetical) measures of the pairwize dissimilarities among the six concepts α, β, γ, δ, ϵ, ζ. The position of each individual in the space R is given by the position vector $R^{\mu}_{(\alpha)}$ whose magnitude $\rho_\alpha = (\sum_{\mu=1}^{r}(R^{\mu}_{(\alpha)})^2)^{1/2}$ where $R^{\mu}_{(\alpha)}$ = the μth component of the αth position vector. Each column vector represents a reference vector orthogonal to each other reference vector (eigenvector) whose length is given by

$$\rho_\mu = \left[\sum_{\alpha=1}^{k} (R^{\mu}_{(\alpha)})^2\right]^{1/2} \tag{8}$$

where λ_μ is the μth root of the characteristic equation for B.

After several repeated measures, assume we have established that the concepts are not in motion relative to one another. Assume further that, at this point in time, all n oberservers receive a message which says, in English,

S_1 "α is β"

This message, the categorical assertion of identity, we call a "simple message." Since it is a categorical assertion of identity, it is the strongest form of simple message. A weaker simple message might say "α and β are similar."

Subsequently a series of additional measures across time are taken. We now must make several assumptions, each of which may be falsified by the observations if they fail. First, we may assume that the message will result in some changes in the configuration of vectors. If this is so, the eigenvalues and eigenvectors of B will be different for the postmessage measurements than for the premessage measures. These differences may be certified within probability parameters by standard statistical procedures; correlations of corresponding eigenvectors across time may be statistically nonunity; cannonical correlations of the $R^{\mu}_{(\alpha)}$ across Δt may be statistically nonunity by chi-square criteria: mean differences between position vectors may be statistically significant by ANOVA procedures, and so forth. Row interactions and row $\times$ column interactions in N way repeated-measures analysis of variance may be performed on either the coordinates of R or the distance matrix $\bar{\mathbf{S}}$ to determine whether specific concepts or specific pairs of concepts are differentially affected by the message (see Gillham and Woelfel, 1977; Woelfel *et al.*, 1975, Woelfel & Danes, 1979).

Second, we might assume that only the concepts referred to in the message will be directly affected by the message. If this is true, then a rotation and translation[3] of the coordinates across any interval of time could be found for

[3] We are restricted to rotations and translations since these "rigid notions" preserve distances (separations) within time periods.

which all differences $R^{\mu}_{(\alpha)t_1} - R^{\mu}_{(\alpha)t_0} = 0$ where the αth concept is not implicated in the message, but where $R^{\mu}_{(B)t_1} - R^{\mu}_{(B)t_0}$ does not equal zero if concept is mentioned in the message. This transformation is given by translating both R_{t_0} and R_{t_1} to an origin at the centroid of those concepts thought to be unaffected by the message (or on one of those concepts itself), and rotating about this origin until the squared distances among the hypothetically stable concepts are at a minimum. If the hypothesis is correct, these differences will be zero by statistical criteria, whereas the distances between the manipulated concepts will be nonzero by the same criteria. If this hypothesis is false, no such rotation can be found.

A stronger version of the hypothesis would predict not only motion versus stability, but also the direction and magnitude of such motion. Mature, trustworthy hypotheses about the direction and magnitude of resultant motion can only be made after many careful observations within the system, but initial guesses based on our understanding of the meanings of English words and their effects can provide useful starting points.

The meaning of the English words in statement S_1 imply that the observer has overestimated the separation between α and β. If, in general, people attempt to comply with the meaning of the message—that is, adjust their view in the direction of the view expressed in the message—then, in general, the distance between α and β should be reduced by receipt of the message. This relative motion may be differentially attributed to $R^{\mu}_{(\alpha)}$ and $R^{\mu}_{(\beta)}$ in Figure 3.1. By con-

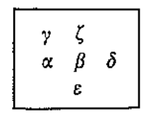


Figure 3.1. Hypothetical representation of first principal plane of the space of 6 concepts α, β, γ, δ, ε, ζ.

vention, the force of this message may be defined as the sum of magnitudes of vectors F_1 and F_2 where $|F_1| = -|F_2|$. Since, by definition, the force F is equally attributed to each concept R^{μ}, differential displacement along the $R^{\mu}_{(\alpha)} - R^{\mu}_{(\beta)}$ vector must therefore be attributed to characteristics of the $R^{\mu}_{(\alpha)}$. That quality of the $R^{\mu}_{(\alpha)}$ which differentially resists acceleration (or displacement) is called *inertial mass*, which is given by

$$\frac{m\beta}{m\alpha} = \frac{|\Delta \mathbf{R}^{\mu}_{(\alpha)}|}{|\Delta \mathbf{R}^{\mu}_{(\beta)}|} \tag{9}$$

We seek now to determine some distance-preserving transformation such that the ratios of the respective $|\Delta \mathbf{R}^{\mu}_{(\alpha)}|$'s remains invariant across repeated messages and over time or in which the ratios of the $|\Delta \mathbf{R}^{\mu}_{(\alpha)}|$'s are known functions of some measurable events. Such an outcome would be an inertial reference frame, and within this frame, the known values of the ratios of the $|\Delta \mathbf{R}^{\mu}_{(\alpha)}|$'s constitute valuable information about the differential magnitude of the response of the $\mathbf{R}^{\mu}_{(\alpha)}$'s to messages.

Strict confirmation of the hypothesis that the message may be represented as a force vector on a line through the two concepts in the message by an observed angel of

$$180^{\circ} = \cos^{-1} (\mathbf{R}^{\mu}_{(\alpha)} \cdot \mathbf{R}^{\mu}_{(\beta)}/|\Delta\mathbf{R}^{\mu}_{(\alpha)}||\Delta\mathbf{R}^{\mu}_{(\beta)}|) \tag{10}$$

to within statistical criteria. Strict confirmation of the inertial hypothesis is given by the criterion

$$\frac{|\Delta\mathbf{R}^{\mu}_{(\alpha)}|/|\Delta\mathbf{R}^{\mu}_{(\gamma)}|}{|\Delta\mathbf{R}^{\mu}_{(\beta)}|/|\Delta\mathbf{R}^{\mu}_{(\alpha)}|} = \frac{|\Delta\mathbf{R}^{\mu}_{(\alpha)}|}{|\Delta\mathbf{R}^{\mu}_{(\beta)}|} \tag{11}$$

for all values of α, β and γ.

Compound Messages

A yet more complex hypothesis might suggest a useful combination rule. We might hypothesize, for example, that English sentences average like vectors, that is, the meaning of the English sentences "α is β" "α is γ" (or perhaps, "α is β and γ." These are called here "compound messages."

If sentences average like vectors, then the resultant vector $\hat{R}^{\mu}_{(\alpha)} = (R^{\mu}_{(\beta)} + R^{\mu}_{(\gamma)})$ can be considered a single message vector resulting in $R^{\mu}_{(\alpha)}$ moving along the vector $\hat{R}^{\mu}_{(\alpha)}$ with an acceleration a inversely proportional to m_{α}.

These hypotheses also are easily falsified, requiring yet more complexities to be allowed in the theory. The important point, however, is to illustrate that the rejection of hypotheses leads directly to the development of successively more accurate, if perhaps more complicated descriptions of processes, and correspondingly more complicated hypotheses which correspond to observations to within increasingly better approximations.

Once the systems has been set into motion, it iteratively improves its fit to observations while providing a consensus among observers within which this increasing pool of comparable observations may be interchanged. The result is a tendency toward individually and collectively enhanced observational capacities, reasoning ability, and access to information for those who use the system.

Once an inertial reference frame has been stipulated, hypotheses consist of statements about the forces generated by different events in the inertial frame. Failure of these hypotheses (e.g., the hypothesis that suggests a message-like $\mathbf{S}^1$ will result in forces along the vector connecting the concepts linked in the message, which in turn results in motion only along this vector) requires stipulation of an additional force (in this case, acting to produce motion out of the anticipated vector). Research must then uncover observed events in the frame corresponding to the residual force vector inferred by the motion out of the predicted vector.

A Current Assessment

Theories are traditionally evaluated in the social sciences on two grounds (*a*) the reliability of their measures; and (*b*) the extent to which outcomes predicted by the theory conform to observed outcomes (validity). In terms of these criteria, this theory compares favorably with competitive theories. Many careful studies have shown reliabilities above those considered requisite by most social scientists (Barnett, 1976; Cody, 1976; Gillham & Woelfel, 1976; Marlier, 1974). Moreover, outcomes predicted by the theory have been in good conformity with observation. Barnett, Serota, and Taylor (1974) interviewed by telephone a small sample of registered voters in a United States congressional district to determine the set of concepts they mentioned most frequently while describing an upcoming congressional race. Sixteen of these concepts were included in a Galileo questionnaire that was administered to a larger sample and the results entered into an early version of the Galileo computer program. Based on the resulting solution, they advised a little known candidate in his first attempt at public office as to the optimal set of messages he should send to the electorate, to move himself closer to the location of the "me" or average voter's position in the space. Two subsequent measures showed that this message had the desired cognitive effects—that is, the candidate moved as predicted. As a consequence, this political newcomer defeated his experienced opponent (the incumbant congressman) with nearly 60% of the vote (Barnett *et al.*, 1974).

Similarly, in a later, more sophisticated laboratory experiment, Cody (1976) entered similar data into the Galileo 3.9 computer program which utilized Eq. (8) through (12) to determine the optimal message strategy to increase successfully the credibility of two moderately well-known political candidates. Similar procedures have been used commercially to aid in the diffusion of educational innovations; the formation of statewide organizations for special education; to aid in the reformation of a state educational system, and to aid in the sale of commercial products and services. In each of these and other cases, the results have been more precise and informative than those yielded by already proven existing procedures, and their dollar value has greatly exceeded the costs of the research.

While the extent to which this system will prove useful in basic attitude–behavior research is still open, Gillham and Woelfel (1976) have shown that it may be used in lieu of much more tedious conventional methods. Barnett (1976) showed that these procedures were able to detect effects of bilingualism on cognitive processing too small to be detected by the most sensitive of conventional scaling methods. Danes *et al.*, (1978) have shown in laboratory experiments that the "inertial mass" hypothesis expressed in the theory (see Saltiel & Woelfel, 1975) accounts for resistance to attitude change far more accurately than plausible conventional models. Marlier (1974, 1976) showed in a laboratory experiment that the set of transformations designated by the theory account very accurately for differences in individual perspectives about railroad nationalization. Brophy (1976) showed that a sizable portion of the variance in perceptions of members of an academic department, as measured by these techniques, could be accounted for by their positions in a communication network. Wakshlag and Edison (1975) showed that these procedures produced measures of the credibility of message sources more precise than conventional semantic differential and factor analytic models. Serota, Fink, Noell, and Woelfel (1975) showed that these procedures provide precise measures of the differential perceptions of the United States power structure across levels of socioeconomic status. Danes and Woelfel (1975) showed that these techniques produce more reliable information for a given sample size than do traditional ordinal scaling methods. Craig (1975) showed the system produced extremely stable measures of the perceptions persons held about nations, although ambiguities in the persuasive messages he generated from the theory precluded unambiguous tests of its dynamic assumptions in his experiment. Mistretta (1975) showed that the system made accurate predictions about the perceptions of crimes and their penalties consistent with Durkheim's (1951) predictions. Barnett (1972) showed that the system yields stable and reliable outcomes even under adverse conditions such as cross-domain scaling and across politically turbulent circumstances. Gordon (1976a) showed that these procedures provide accurate measures of the perceptions of radio stations and their program formats precise enough to predict observed listening patterns, and further showed (Gordon, 1976b) that changes in the metric established by the experimenter yield ratio-level changes in scaling outcomes.

This evidence shows that the theory compares quite favorably with other social science theories in terms of traditional reliability and predictability figures. But such data can be seriously misleading, if one considers only the extent to which the measured data provided by the theory are reliably (reproducibly) measured and the outcomes predicted by the theory are confirmed by these observations. Although the measures yielded by the theory are in the range of the reliabilities of traditional theories (or usually somewhat higher) the fineness of gradation of the measures is usually two or more orders of magnitude better, and the quantity of information yielded is proportionately higher. Clearly, if one measure provides 100 units of information at 90% reliability, and a second provides 10 units of information at 90% reliability, the former measure is preferable by an order of magnitude difference.

This same reasoning applies to the confirmation of predicted outcomes. A proper evaluation of the theory in contrast to others should note that, not only are the outcomes predicted by the theory confirmed to smaller tolerances (usually by about a factor of two or more), but the predicted outcomes themselves are more complicated by far than those derived from earlier theory. The theory presented here, in other words, predicts outcomes about which earlier theories are generally mute or indecisive, and finds these predictions confirmed within smaller tolerances than the cruder predictions of earlier theories are confirmed by methods appropriate to them.

Whereas these experiments support the key premises of the theory, it should be clear from the preceding discussion that the construction of a useful theory is a lengthy collective social process requiring not only causal hypotheses, but the development of symbol systems, logical roles of combination, measurement rules, and a relatively large cadre of trained users even before information substantial enough to warrant hypothesis formulation can be collected.

Ultimately, any theory is to be judged on the extent to which it makes correct, useful, and informative statements about problems of real human interest on the basis of observations that can be made at a cost commensurate with their use value. A good theory, therefore, must make the solution of some class of human problems easier. The more important the problems, and the easier and more certain the solutions, the better the theory.

On first reading, it may be difficult to see how the tedious equations of the preceding pages can make the solution of human problems easy. In fact, however, once mastered, this system does vastly simplify important human activities. Although the derivation of the equations presented earlier was strenuous work, once derived, they need not be derived again for each use. In fact, all of them have been encoded into computer software, which makes the tedious logical manipulations they entail quite automatic. It will be the pragmatic ease with which this theory can enable us to solve difficult and important problems that determines its ultimate acceptability.

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