OVERVIEW: READINGS IN THE GALILEO SYSTEM[1]

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The purpose of this chapter is to provide an overview of the Galileo System and the background necessary for understanding the remaining chapters of this book. **Readings in the Galileo System** is organized into three sections, theory, methods and applications. The chapters in each section are representative of the research performed by over 100 scholars from the disciplines of communication, information science, management and sociology. These readings were selected because they deal with important issues in Galileo theory not readily available in published sources. Thus, this volume is intended to supplement the extensive published literature which describes and uses the Galileo paradigm. A comprehensive bibliography of these materials is provided in an appendix.

This chapter begins with a brief conceptual description of Galileo which will be elaborated and clarified in the chapters which follow. It does not provide a technical description of the Galileo System. Readers interested in such material are referred to Woelfel and Fink (1980) and the various chapters in this volume, particularly part two.

This chapter begins with a brief conceptual description of Galileo which will be elaborated and clarified in the chapters which follow. Next, it discusses the historical development of the Galileo System indicating the significance of each chapter. A typology is developed which categorizes Galileo theory and research based upon its focus on either micro or macro-level phenomenon and as to whether the research may be considered structural or processual. The theoretical and empirical chapters in this volume focus primarily on macro or socio-cultural processes rather than research which uses individuals as the unit of analysis. Finally, the methodological chapters are discussed from Kuhn's (1962) paradigmatic perspective of normal science. In this way, each chapter, theoretical, methodological and empirical is placed into perspective.

THE GALILEO SYSTEM

The Galileo System may be considered a paradigm, an integrated theoretical and methodological model for describing and predicting cognitive and cultural processes as changes in the relations among sets of cultural "objects" or concepts. Generally, the discipline of communication takes these objects to be symbols. Stated explicitly in the model are a set of methodological procedures. The interrelationships among these objects are measured by direct magnitude estimation pair comparisons. The resulting dissimilarities or distances then undergo a set of mathematical operations similar to multidimensional scaling. The result of these transformations is that each of the objects is represented as a point in a multidimensional Riemann space. As a whole, the space

represents the structure or state of the measured cognitive or cultural system. The measurement process are generally repeated over time such that cognitive or cultural processes maybe defined within Galileo as the motion of these objects relative to one another within the space. The algorithms which perform these transformations and calculates the changes between spaces are contained in set of computer programs also known as Galileo.

Because of the resemblance of the coordinate system to physical systems, Galileo researchers have developed a general theory of cognitive and cultural processes modelled by these methods and based upon the principles of thermodynamics and information theory. For these reasons the specific theories are straight-forward generalizations of Newtonian and relativistic dynamics. Much of the research (including that contained in this volume) has shown that the generalized equations from mechanics conforms to observed outcomes more closely than theories written specifically to deal with human behavior. This is due in part to the isomorphism between the theories and the measurement system employed to test them. Notwithstanding humanistic objections, the high level of prediction has led to powerful explanatory theories of individual and social behavior. Within Galileo, messages are treated mechanically as forces which alter ongoing cognitive or behavioral processes. The degree of change that a message produces depends upon how discrepant it is and the number of messages which produced the contingent state of cognition or culture.

The application of mechanical and mathematical principles often gives rise to engineering applications. In the case of Galileo, the specific theories and methods may be applied to modify cultural and cognitive processes in planned ways. Thus, this paradigm allows for control which has been demonstrated in the political and commercial arenas.

THE HISTORY OF THE GALILEO SYSTEM

The Galileo System represents the first paradigm for all the social sciences. While its origins may be traced back to Aristotle and British Associational philosophers of the 18th and 19th centuries, its immediate roots lie primarily in Sociology, Psychometrics, Physics and the field of Communication. From the Sociologists, in particular, Emile Durkheim and George Herbert Mead came the notions of the dynamic self and culture as the collective consciousness. Both concepts are emergent properties of interaction--the exchange of the messages among individuals and groups. The self is defined in relation to other objects or categories of experience. Self-concept changes as new messages define the relationships among these objects (including the self). Thus, an attitude toward any particular object may then be defined as the dissimilarity or distance of that object from the self.

The collective consciousness is a property of the whole society. It exists external to the individual, yet it is best expressed as the average state of the group. It is dynamic to the extent that as new members enter society through birth or

immigration and old members leave through death or emmigration, the collective representations or definitions of cultural objects change. This emergent property of society is described by Galileo as relations among a set of cultural objects as viewed by a representative sample of its members.

From the psychometricans came Galileo's measurement procedures; Thurstone's (1927) method of pair comparison, Steven's (1951) demonstration of the ability of humans to use ratio scales and the spatial models which resulted from the application classical metric multideminsional scaling (Young & Householder, 1938; Torgerson, 1958). The selection of these operations rather than the accepted practices which used categorical scales such as Likert's summated scales (1932), Thurstone and Chave (1929) method of equal appearing intervals or Osgood's semantic differential scale (Osgood, Suci & Tannenbaum, 1957) proved advantagous. As a result, Galileo avoided the pitfalls of other spatial models generated from factor analytic solutions, such as, Osgood's Affective Semantic Space.

It is worth noting that the theories and methods of Charles E. Osgood came closer to a comprehensive paradigm for the social sciences than any predessor. This is evidenced by their widespread adoption for the investigation of language (Osgood, May & Miron, 1975), attitudes and communication phenomenon (Emmert & Brooks, 1970), and subjective culture (Triandis, 1972). They have certain methodological problems which prevent their use as a generalized measure of structure and the application of the laws of Newtonian and relativistic dynamics. Lengthy critiques of the Semantic Differential are provided here by Marlier and Cody (chapter 5) and Danes and Woelfel (chapter 9).

From the physicists, Newton, Descartes, Lagrange, Gauss, Gibbs, D'Alembert and Einstein came the notion of mechanics--how to mathematically describe and explain the changes in multidimensional spaces over time. Of course, the paradigm is named for Galileo Galilei, the astronomer and physicist and founder of the science of dynamics and intellectual impetus for the philosophical orientation known as positivism. Galileo's intellectual traditions are expressed throughout this volume.

The specific development of the Galileo System began while the Joseph Woelfel was studying the status attainment process at the University of Wisconsin in the mid 1960's. Woelfel and Haller (1971) were investigating interpersonal influences upon attitudes towards the level of education and occupational prestige to which students aspired. Each of the expectations of each individual's significant others could thus be represented as a value on a continuum (e.g. the number of years of education) rather than as a categorical label such as doctor, lawyer, plumber or teacher. For lack of a more sophisticated theory, these multiple expectations were averaged to yield an average level of expected attainment. To the researchers surprise, this variable accounted for more than half the variance in the students' attitudes toward future careers. Scrutiny of the logic of averaging led to the realization of the

potential of the theory implicit in this operation. It turned out that the average of any set of diverse expectations represents a least-squares balance point at which the resulting stress ought to be a minimum. Such notions evolved into the Linear Force Aggregation Theory presented in chapter 2. Woelfel wrote it in 1971-1972 while the editors were at the University of Illinois. Subsequent research (Woelfel & Hernandez, 1970; Mettlin, 1973; Woelfel, Woelfel, Gillham, & McPhail, 1974; Saltiel & Woelfel, 1975; Danes, Hunter & Woelfel, 1978) has provided strong support for this theory.

At the same time, the question was raised, "Could discrete objects such as occupations or particular behaviors be placed upon a continuum such that the averaging theory could be applied to predict attitudes and behavior toward specific cultural objects?" Quickly, it became apparent that the perceptions of cognitive objects varied simultaneously along a number of attributes or dimensions, suggesting the use of multidimensional scaling to measure the relations among these object. One problem, however, was that the most widely accepted algorithms for multidimensional scaling were nonmetric (Shepard, 1962; Kruskal, 1964). These relied upon traditional measurement procedures and then applied nonfunctional transformations to improve the fit of the data within a given dimensionality. This operation was based upon the assumption that the data were only ordinal. Nonmetric scaling often distorted the resultant structure and had the effect of rendering the solution unusable for the study of change among the spaces (Woelfel & Barnett, 1982). As a result, the initial research which has evolved into the Galileo System concerned the development of metric software and subjects' ability to reliably perform direct magnitude estimates of the discrepancy among pairs of cultural objects or symbols.[2]

Wisan (1972), Gillham (1972) and Barnett (1972) demonstrated that subjects could reliably perform the measurement operations necessary for metric scaling and that the obtained results were valid. Barnett (1972) took randomly selected samples of varying size from two pools of subjects who completed two different Galileo instruments. One dealt with behaviors and the other abstract concepts. Measures were taken at two or three points in time. He correlated the comparable coordinates which resulted from the scaling operation at each time point. He found that the reliability coefficients increased as a function of the sample size, reaching .97 with as few as 50 cases. This suggested that subjects could perform direct magnitude estimates reliably. An examination of the symbols' loadings on the coordinates suggested that the results were valid and relatively stable over time.

Gillham (1972) (described in detail by Gillham & Woelfel, 1977) examined the changes in the perceptions of a university faculty over three points in time by students, staff and the faculty members themselves. He found that the concepts (the professors' names) were relatively stable but changed as a function of the information the subjects received about them. Additionally, there was greater change for subjects who had less

prior information about the concepts. Further, Gillham demonstrated that the arrangement of the concepts in the space was theoretically valid. The perceived political positions of the faculty and their degree of quantificativeness of their research were regressed on the spaces' coordinates. The multiple correlations for these two attributes were .92 and .78, indicating that Galileo produced a stable and precise coordinate system.

Based on Gillham's research a group of graduate students at the University of Illinois under the direction of Joseph Woelfel attempted to study the effects of "Earth Week 1972" on university students by observing the movement of a number of environmental concepts over time. (This study is reported in detail by Barnett, 1974 and Woelfel & Barnett, 1974). The measurements were intended to occur once prior to Earth Week, once during the events and once after. Specifically, the study was designed to predict the movement in the space as a function of mass media and interpersonal information that the subjects received about environmental topics.

Data were gathered on April 14, 28 and May 19, 1972. However, due to unanticipated events, little environmental information reached the subjects. On April 16, the Defense Department announced the bombing of Hiaphong, Viet Nam and the mining in its harbor. On April 19, the university was besieged with rioting in protest. Store windows in the business district were broken and the there was looting. This continued for a number of days, despite the presence of the state police. The planned environmental programs were suspended or ignored. Between the second and the third data points, George Wallace was shot while campaigning in Maryland (May 15). However, there was a great deal of information about certain concepts scaled in the space--the War In Viet Nam, Crime, and the Most Serious National Problem (MSNP). Additional information about these topics was made available in open forums and leaflets which discussed these issues. There was little information concerning the ecological topics.

The results indicated that the concepts moved in "lawlike" patterns. The concepts about which there was a great deal of information, the War in Viet Nam, Crime and MSNP moved to a greater extent than the environmental terms scaled in the same space. This was due to the additional information the subjects received about them.

The extent of redefinition became more profound when examinations of the concepts' trajectories were made. Both The War and Crime moved in the direction of MSNP. The War seemed to be lagging behind MSNP. The War's time two location was near the time one location of MSNP. The time three location of The War approached the time two position of MSNP. Crime followed a similar pattern. While there was movement of other concepts, it was difficult to assign direction to them. They appeared to move toward the original time one position between the second and third measurements.

These findings clearly lacked the rigor necessary to test the hypothesis that motion in multidimensional space was a function

of the amount of information the subjects received. They did however, provide the impetus for future research by suggesting that Galileo researchers should investigate problems of dynamics (chapters 7 & 8) and the need for a method to compare spaces which took into account the variability of the concepts' (chapter 13). Further, they suggested a relationship between the arrangement of the cognitive elements and behavior. Could one predict the behavior of aggregate cultural groups by the average spatial configuration?

An attempt to answer this question led to a series of Galileo studies which focused on political campaigns (Barnett, Serota & Taylor, 1974, 1976; Barnett, 1981). Election campaigns were chosen because they provided a single point in time at which the behavior of the members of a cultural group would be simultaneously directed toward a single domain of concepts (candidates political parties and campaign issues) and a single behavior, voting. Data gathered as close to election day as possible could be compared with election returns to examine the relationship between the Galileo space and the behavior of the aggregate cultural group. By examining the changes in the spatial manifold over time, one might be able to describe campaign trends, such as a candidate's momentum. Comparisons of these changes with the ongoing events as reported in the media and evaluated through content analysis could be used to determine the impact of information on the dynamics of the cultural space.

In the fall of 1972, the editors moved from Illinois to the Department of Communication at Michigan State University. Galileo was presented to a new group of scholars whose focus was explicitly communication. They had a series of new theoretical and substantive problems which would eventually be incorporated within the paradigm. Due to the time it took to convert the Galileo software to a different computer system (not an easy task in 1972, especially for social scientists) and the training of an uninitiated group of scholars, both in East Lansing and throughout the field of communication, little empirical work was initially conducted. However, the training often took the form of writing explanations of Galileo and syntheses and summaries of previous research. Written in this period were Woelfel and Saltiel's "Cognitive Processes as Motions in Multidimensional Space," (chapter 3) and Woelfel's "Procedures for the Precise Measurement of Cultural Processes" (1974) and a "Theory of Occupational Choice" (1975). This later monograph provided the theoretical foundations and substantive focus of the chapters by Saltiel, "Perceptions of Occupational Names," (chapter 16) and Woelfel, Holmes, Newton and Kincaid, "An Experimental Measure of the Mass of Occupational Names", (chapter 17).

Edward L. Fink, a friend and associate of Joseph Woelfel since the occupational aspiration research at Wisconsin, joined the faculty at Michigan State in 1973. Their collaboration led to the "The Measurement of Communication Processes: Galileo Theory and Method. Published in 1980, it provided a comprehensive overview of Galileo System.

The students at Michigan State applied the paradigm to a wide range of problems. They included, Kim Serota, Richard Holmes, John Marlier, Michael Cody, Jeffrey Danes, Rolf Wigand, James Danowski, N.J. Stoyanoff, Terrance Albrecht, Mark Miller, James Dinkelacker, Felipe Korzenny and many others. Their research, both published and presented at conventions is cited in the bibliography in the Appendix. Of particular merit were Kim Serota and Richard Holmes development of the second generation Galileo software, which made the application of Galileo theory much more convenient. Also noteworthy was Serota's research on political communication and ideologies. John Marlier extended Galileo to Social Judgement Theory and with Michael Cody applied Galileo to Implicit Personality Theory and the notion of source credibility ("Measurement of Perception of Multiple Attributes of Communication Sources: A Metric Multidimensional Alternative to Factor Analytical Models", chapter 5). Jeffrey Danes focused upon the methodological advantages of Galileo ("An Alternative to the 'traditional' Scaling Paradigm in Mass Communication Research Multidimensional Reduction of Ratio Judgements of Separation", chapter 9) and its application to test models of attitude change (Danes, Hunter and Woelfel, 1978).

Three trends in the development of the Galileo System began in the mid 1970s. One was the refinement of the instrumentation and other methodological improvements. Two was the application of Galileo to practical problems, and three was the generalization of the paradigm to describe all changes in structures over time. Thomas Gordon's "Subject Abilities to Use Metric MDS: Effects of Varying the Criterion Pair", (chapter 10) exemplifies the first trend. Barnett and Woelfel's (1979) research concluded that all dimensions upon which there was variance rather than a limited subset should be included in the description of cognitive and cultural processes and that the "true" dimensionality of a process could only be determined by over-time measurement.

Later the same authors (Woelfel & Barnett, 1982) concluded that those processes were not only multidimensional, but non-Euclidean or Riemannian as well. The variance on those dimensions with negative eigenroots was stable across time and the concepts' locations on these dimensions reliable.

These last two papers forced a revision in the method used to compare the coordinates at different points in time (or across groups). Early Galileo research compared loadings on only the first few dimensions and researchers tried to minimize the variance on those dimensions with negative roots. With the evidence reported by Barnett and Woelfel (1979) and Woelfel and Barnett (1982) changes were made to accomodate all the dimensions even in the problematic situation where the number of real and imaginary dimensions differed between two spaces. Further, the method for comparing the coordinate spaces was adjusted to take into account the relative stability of the scaled objects which resulted from their variable inertial mass. Woelfel, et al., (1975) described an algorithm for this purpose. However, due to its complexity and lack of testing it had substantial shortcomings. Woelfel, Holmes and Kincaid,

"Rotation to Congruence for General Riemann surfaces Under Theoretical Constraints," (chapter 12), presented a revised algorithm. Methodological refinements of the Galileo method continue today. Woelfel and Pruzek (1983) describe a method to scale cultural objects as regions, rather than points, in an Euclidean space.

The second trend was the application of the Galileo System as a tool to develop and evaluate messages used in political, marketing and advertising campaigns. Initially, Galileo was used only to monitor changes in cultural processes such as public opinion. While polling for a congressional candidate (Barnett, Serota & Taylor, 1976), it became necessary to develop a communication campaign. This was done through a visual examination of a multidimensional space in two dimensions. A target vector was constructed from the candidate to the self. Then, pairs or concepts (issues or political parties) were used to construct vectors, such that when the parellelogram was completed, the vector which appear the closest to the target vector was selected as the best message. While the resultant message proved effective, the candidate won in a landslide, the researchers felt that a more precise message strategy could have been developed. This solution would include all the dimensions, rather than only those which could be visualized, and an exact mathematical algorithm. "A Multidimensional Scaling Bases Procedure for Designing Persuasive Messages and Measuring Their Effects" (chapter 13) by Woelfel, Holmes, Cody and Fink (1976) is that solution. Immediately, it was tested (Serota, Cody, Barnett & Taylor, 1977) to determine the extent to which it improved the quality of messages.

Quickly, it became apparent that Galileo had commercial applications. These were performed. For example, "An Associational Model for the Diffusion of Complex Innovations" (chapter 4) describes how the Galileo System may be applied to the diffusion of innovations or commercial products. "An Examination of the Diffusion of Automated Ordering Methods in the Pharmaceutical Industry" (chapter 15) by Beninson Germando, Barnett, Dinkelacker and Downing demonstrates this application to problems of communication technologies within the pharmaceutical industry.

The third trend was the extension of Galileo to all phenomenon related to cultural and cognitive processes into a general paradigm for the examination and manipulation of structure over time. Barnett's "A Paradigm for the Measurement of Meaning" (1975) and "Frequency of Occurrence as an Estimate of Inertial Mass" (chapter 14) represent an extension of Galileo to linguistic processes. Kaplowitz and Fink's (1983, 1984) research incorporates all psychological models of attitude change into the Galileo paradigm (e.g., see chapter 7).

In 1977, Joseph Woelfel became a fellow at the East-West Communication Institute in Hawaii. George Barnett followed two years later. This brought the authors into contact with leading scholar from both sides of the Pacific. Among them were D. Lawrence Kincaid, Chung Ying Chang, June Ock Yum and Barbara Newton. Kincaid's interests in thermodynamics, information

theory, network analysis and convergence theory (Kincaid, 1979; Rogers & Kincaid, 1981) provided the influence for Galileo to incorporate a model for network analysis and equilbrum or stationary principles indicitive of cultural convergence. In "Communication and Cultural Convergence" (chapter 6), Kincaid develops his theoretical orientation to these issues. "Precise Procedures for Longitudinal Network Analysis" (chapter 18) by Barnett demonstrates how network analysis may be integrated within the Galileo paradigm. Woelfel's "Variational Principles of Communication" (chapter 8) provides the general statement which suggests that Galileo may be used to describe change in all structures including those which either converge or diverge over time.

Today, Galileo scholars are spread all over America and throughout the world. The Galileo computer program is operational on over 20 academic computer systems with versions for IBM, CDC, DEC, and UNIVAC mainframe and minicomputers. Over one hundred scholars have contributed to the extensive Galileo literature cited in the Appendix. As with any paradigm Galileo has been applied to a wide range of phenomena. Among the areas research with Galileo are intercultural communication (Adams, 1978; Barnett, 1974, 1976, 1977; Barnett & Kincaid, 1983; Barnett, Wigand, Harrison, Woelfel & Cohen, 1981; Kincaid 1979; Kincaid, Yum, Woelfel & Barnett, 1983; Wigand & Barnett, 1976), organizational and professional communication (Albrecht, 1979; Barnett, 1979; Barnett & Carson, 1980, 1983; Brophy, 1977; Harkins, 1979; Siegel, 1976; Quinn, 1982 Carrier, 1983), political communication (Barnett, 1981; Barnett, Serota & Taylor, 1974, 1976; Serota, Cody, Barnett & Taylor, 1977; Block, Woelfel, Dinkelacker & Saxton, 1979), mass communication (Woelfel & Barnett, 1974; Baldwin, Greenberg, Block & Stoyanoff, 1978; Barnett & McPhail, 1979), nonverbal communication (Brandt & Barnett, 1980; Kanaga, 1980), interpersonal communication (Craig, 1977; Danes, Hunter & Woelfel, 1978; Wakshlag & Edison, 1975; Cushman, Valentinson & Brenner, 1980), information storage and retrieval systems (Cole, 1979; Danowski, 1983), network analysis (Barnett, 1979; Barnett & Palmer, 1983), marketing and advertising research (Korzenny, Stoyanoff, Ruiz & Ben David, 1978; Woelfel & Kaplan, 1978), health communication (Nehls-Frumkin, 1978), linguistic processes (Barnett, 1977a, b, 1979; Palmer & Barnett, 1983; Barnett, Palmer & Noor Al-Deen, 1984), and Criminal Justice (Gillham, 1980, 1983; Mistretta, 1976, 1977). There are others. The future definately holds the further specification of the functional relations between information and motion within the Galileo manifold and the application to problems unrecognized today.

The section which follows describes the theoretical and empirical chapters which appear in the book in great detail. Their historical contexts' were briefly noted above. This discussion is organized according to a typology of social research developed for this purpose.

A TYPOLOGY FOR THE STUDY OF HUMAN PHENOMENON

The Galileo System represents a significant breakthrough in the social sciences because it provides a single comprehensive system of analysis which may be applied to both micro phenomenon of individuals, including the cognitive variables--attitudes, values and beliefs and to macro phenomenon, such as pubic opinion, culture and language which are emergent properties of groups. One theoretical and methodological model is equally relevant to Psychology, which deals with the individual, Sociology and Anthropology which study emergent properties of groups, as well as, Linguistics and Communication which focus on both levels. Additionally, important aspects of Management, Economics, Political Science and Geography may be examined using the Galileo System.

Traditionally, theories have been constructed to predict and explain either macro or micro-level phenomenon and logical inconsistancies often result when moving across levels. General Systems Theory argues for the notion of hierarchization--lower level systems interact to form higher level ones (Laszlo, 1972). This suggests that system properties should be consistant across all levels. An exception to the trend of developing theory either for individuals or higher-level systems was Parsons (1951) who developed a conceptual or verbal theory relevant to both individuals and societies. Its drawback was its focus upon structure to the exclusion of process. Galileo allows for both structural analysis and for the study of processes. It is a single perspective equally appropriate for the investigation of macro and micro-structures and processes.

These two distinctions form a typology which may be graphically represented as figure 1. One dimension (horizontal) refers to the size of the phenomenon under investigation. Those which focus upon individuals as the unit of analysis may be considered micro, while those which refer to social systems are considered macro. Independent of this distinction is whether the phenomenon being studied is considered to be static or dynamic. This distinction is displayed vertically. While no structure is truly static, the thrust of research of this type focuses upon relations among objects at a single point in time. Examples of Galileo research which focus upon micro-structures would be the study of cognitive structure and complexity (Danowski, Stoyanoff & Barnett, 1977; Stoyanoff & Fink, 1981). The Galileo System may be used to study the structures of macro entities. For example, Barnett (1977a, b) examined the linguistic structure of a bilingual community. Galileo may also be used to investigate micro-processes such as attitude change (Marlier, 1977; Cody, 1980; Woelfel, Cody, Gillham & Holmes, 1980; Gillham, 1983) as well as macro-processes such as the changes in public opinion (Barnett, Serota & Taylor, 1976; Barnett, 1981) and culture (Kincaid, Yum, Woelfel & Barnett, 1983). The chapters which follow are representative of all four types.

	MICRO	MACRO
STRUCTURAL		
PROCESSUAL		

A TYPOLOGY FOR THE STUDY OF HUMAN PHENOMENON

FIGURE 1

MICRO PHENOMENON

Woelfel's "A Theory of Linear Force Aggregation in Attitude Formation and Change," (chapter 2) develops an attitude theory which along with Woelfel and Saltiel's "Cognitive Processes as Motions in Multidimensional Space: A General Linear Model" (chapter 3) have become the theoretical foundations of the Galileo paradigm.

"A Theory of Linear Force Aggregation in Attitude Formation and Change," states that attitudes may be described as rates of behavior along a single dimension. It alludes to the idea that an attitude, at any point in time, may be considered as the generalized mean, having a focus on many different dimensions simultaneously. Woelfel concludes that the attitude of an individual equals the arithematic mean of all the information made available to him/her, that attitude change is inversely related to the number of messages or inertial mass, from which the attitude was formed, and that the heterogeneity of the influences have no consequences for attitude stability.

In "Cognitive Processes as Motions in a Multidimensional Space: A General Linear Model," Woelfel and Saltiel take the linear model of attitude change described above and make explicit the notion that attitudes may be construed as a matrix of discrepancy scores among a set of elements which compose the attitude. This matrix can be transformed into a multidimensional space to allow graphic interpretation. They then provide a theory of attitude change based upon the general linear model which seems to account for most of the empirical evidence about the relationship between information (the degree of change in attitude advocated) and the change in the attitude held. This includes even seemingly anomalous cases such as change in direction opposite than that advocated (the boomerang effect) and other reported departures from linearity.

In "A Spatial-Linkage Model of Cognitive Dynamics", Kaplowitz and Fink (chapter 7) develop a model which describes the dynamics of cognitive processes such as attitudes. It builds on the Galileo tradition articulated by Woelfel and Saltiel in chapter 3, but rather than relying exclusively on a spatial model, it also emphasizes the connections or linkages among a set of concepts. They argue that the "linkage" model is more parsimonious. It posits only one process, the linkage between

concepts, to account for both the motion of a concept in responses to a message, and the resistance of the concept. These three chapters focus upon micro-processes, although Woelfel and Saltiel makes explicit the notion that a single state of a cognitive process, a structure, may be represented by a matrix of discrepancy scores among the objects of an individual's cognitive domain. These ideas were soon extended to macro processes, the focus of this volume. Woelfel's "Metric Measurement of Cultural Processes" (1974) and Woelfel and Barnett's "A Paradigm for Mass Communication Research" (1974) are examples of the initial change in focus from individuals to socio-cultural systems.

MACRO PHENOMENON

Communication research has been criticized for its biases (Rogers & Kincaid, 1981). These biases include a model that views the communication process as linear and one-way rather than cyclic and interactive among participants. The model has a source bias, rather than a focus on the relationships among the interactants; a focus on the objects of communication as simple, isolated, physical objects at the expense of the context in which they exist; a tendency to focus on messages; a concentration on individual psychological effects of communication rather than on the social effects; and a belief in one-way mechanistic causation rather than mutual causation. The editors of this volume share the view that the focus of communication research on individuals has led to a biased perspective. As a result, we have chosen to highlight Galileo theories and research which concerns macro processes--phenomenon such as social perception, language, culture, and the social structure, including the perception of occupations and communication network analysis. These are emergent properties of the communication among people and thus the focus is on higher level units of analysis than single individuals.

In "Measurement of Perceptions of Multiple Attributes of Communication Sources: A Metric Multidimensional Alternative to Factor Analytical Models" (chapter 5), Marlier and Cody propose the use of metric multidimensional scaling as an alternative to factor analytical models for the measurement of social perception constructs such as source credibility, source valence or homophily. The concept of ethos from which source credibility derives is taken to be a property of culture and as such should be labeled as a macro-level phenomenon.

Marlier and Cody demonstrate that the assumptions which underlie factor analysis, in general, and the semantic differential, in specific, are untenable. The reasons the authors give are first, that the meaningful origin and equidistance from the origin of bipolars are artifactual, stemming from the forced association of pairs of points and standardized lengths between end points. The second reason is that the assumption that the meaning of a trait is solely determined by its semantic opposition to its grammatical antonym

and therefore conceptualizing meaning as a compound reaction to bipolar terms is questionable.

Because of these problems, they propose a multiple attribute model generated through metric multidimensional scaling--the Galileo System. This model has none of the problems of factor analytical models and has numerous advantages which the authors describe. The final section of the chapter applies the multiple attribute model to Implicit Personality Theory.

The utility of Galileo as a measure of semantic processes is demonstrated in "Frequency of Occurrence as an Estimate for Inertial Mass" (chapter 14). The chapter begins with a theoretical discussion of the concept of synonym which argues that they should have equivalent positions within semantic space. However, while synonyms refer to the same referent, they do vary in their frequency of use. Following the Woelfel-Saltiel theory (chapter 3), it is expected that the symbol that is used most frequently in natural language would be more resistant to change than its synonym which occures less frequently due to differences in the concepts' inertial masses. Barnett reports that systematic distortions from equivalence resulted due to the symbols's variance in frequency of occurrence in language, such that the more frequently a word is used, the closer it is to one's self concept. Also, the more frequently a word occurred in language, the less attitude change resulted from equivalent messages. Worth noting is the notion that micro and macro processes interact.
Language, a macro phenomenon had important implications for the attitude change of individuals. Thus, the paradigm integrates both perspectives and represents an important contribution to the social sciences.

Diffusion of innovations, be they products, practices or new ideas, often represent the beginning of a complex causal chain which brings about the change in definition of many elements central to soceity and its culture. In "An Associational Model for the Diffusion of Complex Innovations" (chapter 4), Barnett adopts the Galileo paradigm and shows how the diffusion of innovations may be described in the same manner as suggests for cultural processes. Starting from an associative position, i.e., all elements in cognition are organized according to their degree of similarity, he argues that innovation result from a rearrangement of these elements. These innovations, then, must produce some reorganization of related elements as they diffuse through society. It is here that procedures for the precise measurement of cultural processes are applied. The chapter concludes with a series of mathematical models for the prediction of the rate of cultural change over time which results from the diffusion of an innovation.

Beninson Germano, Barnett, Dinkelacker and Downing provide an empirical demonstration of Galileo's utility for describing the changes in culture which result from the diffusion of an innovation. In "An Examination of the Diffusion of Automated Ordering Methods in the Pharmaceutical Industry" (chapter 15), they describe the differences in collective perceptions of

various types of computer based ordering systems among pharmacists at different stages in the adoption process.

"Communication and Cultural Convergence" (chapter 6) by D. Lawrence Kincaid, is a macro processual Galileo theory. The chapter develops communication theory which accounts for large scale processes of cultural convergence and divergence by drawing on the concepts and methods of statistical thermodynamics. Kincaid treats individuals in much the same manner as atoms are treated in thermodynamic theory. Rather than attempting to predict the effects of communication on single indiviudals, the focus of this theory is on the structure of the distribution of mental states of large collectivities which make up cultures. These cultural states may be measured using Galileo. Kincaid demonstrates, based upon the laws of thermodynamics, that information can have only a limited number of possible outcomes on cultural systems. The two most significant of these are convergence to shared meaning when the boundries between the interacting groups are open and divergence to separate meaning systems when the boundries are closed. By examining the interconnections and the integration of a group's social networks prediction about the end state of cultures may be made.

This chapter is also noteworthy because convergence theory is a reaction to the bias model of communication described above. Convergence theory treats communication as cyclic, focuses upon relationships rather than individuals, explicitly uses cultural groups as the unit of analysis, and focuses upon the social effects which result from mutual causation.

While specifically focusing on Galileo's application as a measure of culture, this chapter points the direction of research toward the description of social structures, in general, and communication networks, in specific. There are three chapters which deal with the social structure. Perceptions of Occupational Names: A Multidimensional Scaling Approach" (chapter 16) by John Saltiel, applies the Galileo paradigm to decribe perceptions of occupational labels. Since sociologists generally regard occupation as the foundation of social stratification, this chapter may be taken to be a description of the perception of the social structure. While many sociologists have suggested that occupational structure is multidimensional there has been little progress in its measurement. Saltiel proposes the use of Galileo to portray this structure and presents findings which demonstrate this approach. Thirty-four occupations were scaled and the results reveal two clearly identifiable attributes--prestige and sex. They were determined through regression analysis.

In "An Experimental Measure of the Mass of Occupational Names" (chapter 17) Woelfel, Holmes, Newton and Kincaid, measure a subset of the occupational names used by Saltiel. The purpose of their research was to examine the changes in the occupational structure from experimentally induced messages and to determine the inertial mass of various occupational names. They conclude that precise inertial reference frames of cognitive and cultural phenomenom can be reliably established, that the concept of

inertial mass can be established on an empirical basis and that masses can be estimated to useful levels of precision for experimental purposes.

An alternative conceptualization of the social structure suggests that the structure or organization of society is an emergent property of the regular patterns of interaction of its members. Investigations of this phenomenon are generally known as network analysis. While there are a variety of methodologies for investigating social networks, none has proved superior, especially when the change in networks over time is considered. In "Precise Precedures for Longitudinal Network Analysis" (chapter 18) Barnett demonstrates how the Galileo System may be used to examine the change in networks over time. He begins with a matrix of the frequencies of interactions which are transformed into a matrix of communication distances by multiplying the frequencies by a scalar reciprocal or subtracting them from an arbitrary large constant. The result is a matrix of the same form as is typically entered into the Galileo Program. The metric multidimlentional scaling procedures produces a Riemannian network space which he argues is a logical consequence of spatial modeling of social networks. The chapter next demonstrates how the proposed methods provide insights into the changing activities of the air traffic network among 31 major American cities over the 14 year period, 1968-81. Change in the network was described by two functions, a polynomial which accounted for 75% of the change, and an exponential, which accounted for 86%. This change was attributable to a number of factors. Among them were the economy and the openning of new airports in Dallas-Ft. Worth and Atlanta. Further, the rate of change was described as two epoches. The first (1968-1974) was characterized by a high rate of change, while the second (1975-1981) was relatively stable. The change between these two periods was attributable to the opening of the Dallas-Ft. Worth airport. Finally, the network structure accounts for the physical proximities among the cities. 35% of the variance in latitude and 84% of the variance in longitude were accounted for by the spatial model. These results indicate that Galileo produces valid results when used for network analysis.

While this chapter deals with what is generally taken to be a macro structure phenomenon, it represents an important extension of the Galileo paradigm. All the chapters both theoretical and empirical previously discussed describe cognitive or cultural process as mentalistic phenomenon. The data used to evaluate Galileo theories were gathered by asking individuals to perform direct pair comparisons of the magnitude of the discrepancy among cultural objects. This chapter uses behavioral data instead and treats it in the same manner. Thus, Galileo becomes not simply a method for analyzing mentalistic data but rather a general paradigm to describe change in structure over time. In this case, the structure is the air traffic network among major American cities.

"Variational Principles of Communication" (chapter 8) by Joseph Woelfel cannot be categorized as focusing on either micro

or macro phenomenon. However, its focus is explicitly processual. In the chapter, Woelfel develops a variational (dynamic) mechanical model of communication. Parts of this model have been empirically tested on both attitude change (Barnett, 1981) and cultural processes (Barnett & Kincaid, 1983; Kincaid, Yum, Woelfel & Barnett, 1983). Woelfel develops the model through explicating four necessary logical operations. They are, one, the Cartesian measurement model. Two is the development of functional representation of variables in terms of the ratios given by measurements. Three is the recognition and analysis of residual terms in the functions, and four, the stipulation of minimization or stationary principles.

This chapter is perhaps the clearest expression of the ontological assumptions of the Galileo paradigm. Communication and other social systems should be represented in the same manner as other mechanical systems, rather than by the teleological, categorical and verbal models currently in widespread use. The variational model has many advantages over these models, the least of which is its improvement in predicting human activity (Barnett, 1980; Barnett & Kincaid, 1983; Kincaid, et al., 1983). Further, the mechanical model does not imply that humans act as machines, clockworks or springs but rather suggests simply a wholly abstract logical form of argument. The essence of the mechanical model is the notion of proportionality, ratios of abstract quantities which have important counterparts in experience to the extent that measurements of observations of experience have been made with a proportional measurement system. It is with the adoption of the mechanical variational model that the laws of thermodynamics and their corollaries, information and entropy may be directly and consistantly applied to the science of communication.

GALILEO AS NORMAL SCIENCE

Galileo researchers for the most part have been conducting what Thomas Kuhn (1962) describes as normal science. That is, research based upon past scientific achievements which a particular scientific community acknowledges for supplying the foundations for its future practice. The members of the community expouse an accepted body of theory, articulate its successful applications and use common instrumentation. Together, these provide models from which a scientific research tradition emerges. As individuals are trained in the paradigm, they become committed to the rules and standards. That commitment and consensus over fundamentals are the prerequisites for normal science--the genesis and continuation of a research tradition.

Within the Galileo community, there is consensus regarding the conceptual, theoretical, instrumental and methodological foundations. The theories in the first section of the book form the basis for all Galileo research. Applications, such as, Barnett, Serota and Taylor's (1976) study of a congressional campaign are often cited as evidence of the utility of the paradigm. Between 1978 and 1982, Galileo scholars met annually

at the International Communication Association meetings to explicitly discuss advances in "Galileo" theory, methods and applications. In 1982, these scholars met to explicitly discuss the standardization of measurement procedures and notation used in Galileo research (Barnett, 1982; Marlier, 1982; Woelfel & Napoli, 1982). The reasons for the proposed standards are to improve the communication among scientists and facilitate the development of a shared data base from which generalizations about human activities may be made.

A paradigm does more than simply produce consensus about theory and methods. It provides guidance for the research by focusing attention upon on esoteric problems, parts of nature that should be investigated in detail. The paradigm determines those problems of nature which should be solved. These problems are often the residual ambiguities and apparent contradictions left unresolved by the paradigm or their phenomenon not yet explicitly under its umbrella. Some may be methodological, problems in instrumentation that must be solved in order to increase the precision and reliability of measures connected to the paradigm. This in turn improves the ability to test the paradigm's theories and to make discoveries about nature. The chapters in the methodological section of this book focus upon problematic areas which were resolved, and thus, improved Galileo's ability to describe cognitive and cultural processes and to make predictions or to extend the paradigm's range with additional applications.

The methodological section begins with Danes and Woelfel's "Multidimensional Reduction of Ratio Judgements of Separation: An Alternative To The Semantic Differential" (chapter 9). The authors raise the question, "How do the scaling procedures advocated in this volume compare with traditional measurement techniques? They provide evidence which suggests that the described techniques account for considerably more stable variance than traditional methods and that bipolar adjectives, such as positive and negative, are not equidistant from a common origin or exact opposites on the attribute vector. These results suggest that the basic assumptions underlying Osgood's Semantic Differential Scale are untenable. As an alternative the authors recommend direct magnitude estimates of the dissilarity among pairs of concepts using an agreed upon metric as a standard.

In "Subject Abilities to Use Metric MDS: Effects of Varying the Criterion Pair" (chapter 10), Gordon addresses the problem of selecting a criterion pair and subjects' ability to reliably use a given standard while performing direct pair comparisons. Additionally, the chapter examines the differences in spatial representations that result from varying the criterion standard. In "Procedures for the Precise Measurement of Cultural Processes," Woelfel (1975) makes recommendations for the selection of the criterion pair.

> While the choice of the unit of measure is arbitrary, choice of different standards will have consequences for the pattern of asurement made with the system. Choosing as Rod **S** some ordinary language symbol whose relation to other much symbols is stable over time might make results of the measurement more clearly interpretable in terms of the ordinary language system than would a Rod **S** defined by a symbol whose meaning fluctuates in the vernacular system. Good scaling practice, furthermore would suggest a standard midway between the largest and smallest discrepancy likely to be encountered, so that judgements of extremely large or extremely small discrepancies are minimized.

Because no single standard has been recommended a variety of criterion pairs of varying distance have been used in Galileo research. Thus, an examination of the effects of varying the criterion pair is critical if results are to be generalized beyond a single study. The results have important implications for the improvement of Galileo instrumentation. On the basis of 863 subjects using nine different criterion conditions (three different sets of pairs of varying size), Gordon reports extremely high correlations among the conditions. Also as the size of the criterion pair increases, the resulting space also increases, while configurations, as indicated by the correlations, remains essentially the same. Finally, he indicates that "...the ability to use differing criterion pairs seems to be such that subjects can quite readily use differing standards to describe their perceptions of concept interrelationships..."

Mark Miller characterizes the earlier attempts to assess the reliability of Galileo measurement procedures as problematic (i.e., Barnett, 1972; Gillham and Woelfel, 1977; Gordon, chapter 10) in chapter 11. He suggests the following reasons: 1) They disregard variance about the means of the estimates. 2) They rely on mathematical procedures (rotations of the spaces) that could inflate derived reliability coefficients. 3) Past procedures were arduous, unconventional and ignored useful information in the data. As a result, they have not been employed every time a new data set was gathered. Miller suggests the use of dependability coefficients as alternatives for assessing the quality of direct magnitude estimation data. These procedures make less adruous demands on the Galileo researcher and are well-grounded in psychometric theory. They may easily be applied every time a new set of data is collected because the software to determine the coefficients are part of standard statistical packages. Miller provides empirical examples to demonstrate how the dependability coefficients may be used to determine the quality of Galileo data.

"Rotation to Congruence for General Riemann Surfaces Under Theoretical Constraints" (chapter 12) by Woelfel, Holmes and Kincaid is concerned with the problem of describing the change

between two or more sets of coordinates. The typical practice with Galileo has been to translate the spaces to a common origin and then rotate each space to its immediate predecessor such that the squared discrepancy between the spaces (departure from congruence) is minimized. At that point, one may simply subtract the coordinates of the second space from the first to determine the degree and location of change over a given period of time. The solution may not be this straight-forward when the spaces are non-Euclidean and when the concepts vary in inertial mass. This chapter poses a critical methodological problem for the paradigm to solve if Galileo is to accurately describe the dynamic nature of cognitive and cultural proesses and test the variational model described in section one.

The standard practice in Psychometrics for comparing multidimensional spaces is a Procrustean rotation (Schonemann & Caroll, 1970) which first dilates or contracts the spaces to a common size and performs a least-squares rotation to minimize the departure from congruence. This procedure is unacceptable for two reasons. One, the change in the size or volume of the space may represent true change. The cultural objects may be perceived as more or less similar over time as information about these concepts becomes part of the environment. Two, least-squared rotations to congruence may distort the apparent motion in the spatial configuration. This is because some of the motion is overestimated in certain cases and underestimated in others. As a result, the use of the method is not advantageous because it renders highly complex the apparent motion where simplier laws could describe the actual change. As an alternative, Woelfel, Holmes and Kincaid propose that with the knowledge of additional information independent of the coordinate values more meaningful results may be obtained. This information may be the inertial mass of the scaled concepts or simply whether or not a concept was manipulated in an experiment. When the extra data are available, there are two different solutions to the rotation problem. One is the dichotomous case when only evidence of the manipulation of certain concepts is known. A stimulus is either theoretically dynamic or stable. The other solution can be applied when all the scaled items must be weighted individually. Examples when this solution would be applied is for concepts of different inertial mass. The application of the scheme provides for much more graphic results. Both types of rotations are presented by Barnett (chapter 14) and Woelfel, Holmes, Newton and Kincaid (chapter 17).

The Woelfel, Holmes and Kincaid chapter represents a revision of an earlier algorithm for the comparison of multidimensional Riemann spaces under theoretical constraints (Woelfel, et al., 1975). As is often the case in scientific research, what appears as the optimal solution at one time, later is shown to be inadequate through empirical application or rational argument. This was the case with the earlier algorithm. The later paper corrects these problems and improves the methodological practices of the Galileo paradigm.

The final chapter in the methodological section (chapter 13) is Woelfel, Holmes, Fink and Cody's "A Multidimensional Scaling Based Procedure For Designing Persuasive Messages and Measuring Their Effects" It specifies how messages strategies may be developed and evaluated with Galileo paradigm. These procedures are based upon the Woelfel-Saltiel attitude theory and the empirical findings that the closer a concept is to the self, the more positive the collective attitude and the more frequent the behavior involving that cultural object. Previous applications of Galileo developed message strategies based upon visual examinations of limited dimensionality. Barnett and Woelfel (1979) argued that all the dimensions upon which there is variance should be taken into account when analyzing multidimensional configurations. Psychological and cultural processes are complex and their dimensionality generally exceeds three. This makes visual interpretation difficult and the resultant message strategy less than optimal because certain information is not taken into account when developing the strategy. Thus, the research raised the question, "Could a mathematical solution be derived to determine the maximally effective message strategy regardless of the dimensionality of the spatial manifold?" Woelfel, Holmes, Fink and Cody develop a mathematical solution to this problem through the use of tensor analysis. Conceptually, it operates as follows. A target vector or tensor is constructed between a target concept, generally the self, and the concept to the repositioned in the space. Next, tensors are created from all possible one, two, three and four concept combinations. These are evaluated using the criteria of the angle with the target tensor and the final distance between the position produced by this tensor and the target concept. These are compared and the optimal message selected. It is the one with the smallest angle and shortest distance to the target concept.

This chapter represents an important methodological advance because through its solution the precise application of the theories in the first section of the book to a wide range of communication phenomena is made possible. In a sense, this chapter specifies the first engineering development of the paradigm. Rather than simply observing cognitive and cultural processes and testing theories of human activities, the Galileo System may be used also to manipulate these phenomena.

There continue to be problematic areas to be resolved. For example, Neuendorf, et al. (1987) assessed a variety of self-concept terms in Galileo research and found that for most applications the simple self term (Me, You, Myself or Yourself) was inadequate. Rather, a more precise therm, "My Preference" yielded better predictions. The research continues.

SUMMARY

In summary, this chapter was intended to provide a general introduction to a paradigm for social science research known as the Galileo System. This was done through a brief overview of Galileo, a description of the historical development of the

paradigm, an review of each of the theoretical and empirical chapters based upon their focus upon micro or macro processes or structures and a discussion of the methodological chapters from the perspective of normal science.

NOTES

1. The author would like to thank Joseph Woelfel, D. Lawrence Kincaid, James Gillham and Edward L. Fink for their ideas which helped to structure this chapter and their feedback on its earlier.

2. In any event, the initial Galileo metric algorithm was written before any of the authors had knowledge of the available psychometric materials.

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