THE GALILEO SYSTEM OF MEASUREMENT: PRELIMINARY EVIDENCE FOR PRECISION, STABILITY, AND EQUIVALENCE TO TRADITIONAL MEASURES

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This paper presents the elements of a theory of measurement for communication and cognitive processes, along with specific operationalization of rules and procedures. Longitudinal data taken from a large sociology department are presented to illustrate the use of the method and show its relationship to commonly used procedures. These data show that the new procedures provide scales whose precision of measurement exceeds typical practice while at the same time saving considerable time and effort.

The founding supposition of sociology, anthropology, and other social rather than individual sciences is that properties of groups or aggregates may be studied as phenomena in their own right rather than simply as epiphenomenal consequences of their multiple individual manifestations. Principal among these aggregate phenomena is culture—for our purposes, the aggregate cognitive process of a group, organization, or society. Émile Durkheim refers to the constituent elements of this aggregate cognitive system as "social facts" or "collective representations," and considers them the principal object of sociological study (Simpson, 1963, pp. 17-19):

> Society has for its substratum the mass of associated individuals. The system which they form by uniting together, and which varies according to their geographical disposition and the nature and number of their channels of communication, is the base from which social life is raised. The representations which form the network of social life arise from the relations between the individuals thus combined or the secondary groups that are between the individuals and the total society . . . The resultant surpasses the individual as the whole, the part . . . No doubt each individual contains a part, but the whole is found in no one. In order to understand it as it is one must take the aggregate in its totality into consideration. It is that which thinks, feels, wishes, even though it can neither wish, feel nor act except through individual minds.

While in the past most communication research has focused primarily on the individual and the psychological, recently a number of communication scientists have turned their attention specifically toward these collective representations. Two principal foci of this research may be distinguished, both clearly anticipated by Durkheim: (1) investigation into the relationship between "the system which they [the collective representations] form" and "the nature and number of their channels of communication," which involves a study of the interrelationships between cultural patterns and the social structure, particularly the communication network, underlying them (Gillham, 1972; Woelfel, 1973; Barnett, Serota & Taylor, 1976; Brophy, 1976); and (2) the communication processes between or among several cultural systems (Barnett, 1975a; Barnett, 1975b; Barnett & Wigand, 1975; Wigand, 1975).

This new focus on aggregate cultural variables has brought with it new measurement tasks and possibilities. Most recent work in the area, for example, has used a measurement system[1] called the "Galileo System," a set of techniques which takes advantage of the aggregate character of cultural variables to provide reliable, precise ratio-scaled and multidimensional measurements of cultural processes (Woelfel, 1973, 1974).

While many studies employing this system of measurement have been done (perhaps the majority in the last year), very little information about the operating characteristics of the Galileo system can be found conveniently in the communication literature. This article, therefore, has three related goals: (1) to describe briefly the operations which constitute the Galileo system of measurement, (2) to present data describing the reliability and validity of the system in a typical measurement situation, and (3) to illustrate some of the relations between Galileo measures and more traditional procedures.

THEORY

The Galileo system of measurement is composed of three basic procedures: (1) procedures by which estimates of the discrepancy in meaning among all nonredundant pairs of objects or events of interest are made as ratios to an arbitrary standard discrepancy (called elsewhere ratio judgments of separation [Danes & Woelfel, 1975]); (2) procedures for aggregating the scores taken from individual sample members into a measure of the cultural whole; and (3) procedures for decomposing the resultant matrix of aggregate discrepancies or separations into a mathematical form convenient for over-time analysis.

Ratio Judgments of Separation

These techniques begin by assuming that the process of perceiving and identifying any "object" is basically a process of differentiation, wherein individuals learn to discriminate or separate the stimuli which are the mechanism of the perception of the object from other stimuli representing other objects on the basis of their dissimilarities with regard to certain underlying attributes (Torgerson, 1958). Thus, for example, one identifies a yellow ball as different from a red ball because she or he recognizes them to be dissimilar by a certain amount in terms of the attribute *color*. Although in the example given the two objects differ only in color, most frequently objects differ with regard to many attributes at once. Two persons, for example, may differ in regard to the attributes sex, age, height, political position, and so on through many attributes. The aggregate of all these dissimilarities can be taken as a measure of the overall difference or *separation* between these two persons.

While techniques most commonly used estimate the differences between objects attribute by attribute (i.e., how tall is A; how tall is B, etc.), the Galileo system requires that the overall separation between objects be estimated directly, without specific regard to any attribute or set of attributes. This is accomplished by providing respondents with an arbitrary separation[2] and requiring them to estimate all other separations of interest as ratios to that standard. These procedures are discussed in detail elsewhere (Woelfel, 1973, 1974; Serota, 1974; Danes & Woelfel, 1975; Gordon, 1976). A more general discussion of principles of measurement in relation to procedures of this kind is given in Krantz, Luce, Suppes, and Tversky (1971). While unfamiliar to the social scientist accustomed to "traditional" measures, these procedures do not seem difficult for respondents. An average high school class, for example, can usually complete a 15-concept Galileo (105 pair comparisons) in 20-25 minutes. Respondents interviewed after completing both Galileos and conventional scales usually report Galileo scales require more effort because they allow a more accurate assessment than the cruder scales; respondents usually feel they are worth the extra effort.

The result of this procedure is a continuous numbering system such that two objects judged to be completely identical are assigned a pair-wise separation value of zero (0), and pairs of objects of increasing separation are assigned scores of increasing value. Assuming that the definition of an object or concept is constituted by the pattern of its relationships to other objects, the definition of any object may be represented by a 1 x N vector S, where S_{11} represents the separation of the object from itself (thus $S_{11} = .0$ by definition), S_{12} represents the separation between the first and second object, and S_{1n} represents the separation between the first and *nth* objects. Similarly, a second object may be represented by a second vector S_2, and the definitions of any set of n objects may be represented by the N x N matrix S

$$\begin{matrix} s_{11} & s_{12} & \cdot & \cdot & \cdot & s_{1n} \\ s_{21} & s_{22} & \cdot & \cdot & \cdot & s_{2n} \\ \cdot & \cdot & & & & \cdot \\ \cdot & \cdot & & & & \cdot \\ \cdot & \cdot & & & & \cdot \\ s_{n1} & s_{n2} & \cdot & \cdot & \cdot & s_{nn} \end{matrix}$$

where any entry S_{ij} represents the separation between the *ith* and *jth* objects. Once these separations have been estimated, the scaling theory on which Galileo rests must assume that the matrix S will represent the pattern of differences among the stimuli across whatever attributes the respondent perceives them to differ at the time and under the circumstances that the measurements are made. This hypothesis, which we might call the equivalence hypothesis, makes explicit the relationship between the method of ratio judgments of separation and the more common method of direct magnitude estimation of attributes.[3]

Aggregation

One of the simplest and most obvious procedures available for aggregating the individual respondent's judgments of separations is simple averaging. This, in fact, is the exact procedure followed in Galileo work. Specifically, for any given separation S_{ij}, a random sample of N respondents is drawn from a given culture or group, and these informants' responses are averaged to yield the aggregate cultural separation, i.e.,

$$\bar{S}_{ij} = \sum_{k=1}^{N} S_{ijk}/N$$

where $\bar{S}_{ij}$ = the aggregate cultural separation between i and j, k = the *kth* respondent, and N = the number of respondents.

This procedure, of course, can be made to approximate the "population true average separation" to any degree of precision.[4] The question is what such a measure might represent. Following Durkheim, we might well consider it a measure of cultural belief (Simpson, pp. 26-27):

> Currents of opinion, with an intensity varying according to the time and place, impel certain groups either to more marriages, for example, or to more suicides, or to a higher or lower birth-rate, etc. These currents are plainly social facts. At first sight they seem inseparable from the forms they take in individual cases. But statistics furnish us with the means of isolating them. They are, in fact, represented with considerable exactness by the rates of births, marriages and suicides, that is, by the number obtained by dividing the average annual total of marriages, births, suicides, by the number of persons whose ages lie within the range in which marriages, births, and suicides occur. Since each of these figures contains all the individual cases indiscriminately, the individual circumstances which may have had a share in the production of the phenomenon are neutralized and, consequently, do not contribute to its determination. The average, then, expresses a certain state of the group mind (*l'ame collective*).

No doubt this view of culture as the arithmetic mean of the judgments of all members of the culture will be viewed as an oversimplification by many, but it is precisely this simplicity which constitutes its main advantage. If we assume only for the purpose of argument an individual, previously unsocialized, who receives at random messages $k_1, k_2, \ldots k_n$ about the separation between any two objects i and j, and assume further that some "cognitive consistency" mechanism like dissonance operates, then as N becomes larger, the individual's definition of the separation S_{ij} might be expected to converge on the cultural average $\bar{S}_{ij}$, since $\bar{S}_{ij}$ has the powerful "balance" property

$$\sum_{k=1}^{n} (S_{ijk} - \bar{S}_{ij}) = 0$$

Of course these assumptions are unrealistic: individuals do not communicate at random; they may not weigh each communication from each other person equally, and so on. But nevertheless, $\bar{S}_{ij}$ may be seen to operate as a central tendency in much the way cultural beliefs are thought to work: it is a position toward which individuals may be seen to tend, but (due to deviations from the assumptions of random communication and equal weighting of sources) with which few if any individual's beliefs would be expected to conform exactly.[5]

In addition to the *prima facie* "correctness" of the average as a measure of cultural elements, this procedure gains the considerable advantage of averaging random and individual variance out of the final score. The resulting measure, then, may be expected to be both precise (since it is a continuous ratio scale) and reliable (since random and individual disturbances have been cancelled out by averaging). We might hypothesize, therefore, that the Galileo system will be reliable enough to assess the stability of cultural configurations over time, yet sufficiently precise to measure changes in those same configurations as well, in contrast to traditional ordinal measures, which purchase reliability at the cost of precision of measurement.

Orthogonal Decomposition of the Cultural Matrix

The logic of the procedures presented so far yields a model of cognitive objects separated from each other by "distances" in a cultural "space." Changes in the configuration of this structure over time, therefore, may be viewed analogously as "motions" in this space. For heuristic mathematical reasons it is convenient to refer these motions to a common coordinate system. Fortunately, this is a common problem in nearly all the quantitative sciences, and appropriate mathematical procedures were defined in the mid-19th century by Jacobi (1846), which consist essentially of determining the eigenroots and their associated eigenvectors for the scalar products derived from the matrix S. The same methods were made available to psychometricians in 1938 by Young and Householder, but did not become generally known until reintroduced by W.S. Torgerson in 1951 and 1958 as metric multidimensional scaling. Metric multidimensional scaling consists of a factor analysis of the variance-covariance matrix of pairwise dissimilarities scores, however obtained. Formally,

$$\Sigma = R\Phi R' + \Psi$$

where: Σ = variance-covariance matrix of observed dissimilarities scores, R = a matrix of factor loadings, Φ = a diagonal matrix of intercorrelations among the factors—in this case, $\Phi = I$, and Ψ = a symmetrical matrix of error terms. Each column of R represents a coordinate axis or "factor," orthogonal to all other columns of R, and each row of R represents a variable or "object" as a position vector in the space R. Differential stability of the columns or factors of R would indicate differential stability of the cultural configuration in certain directions; differential stability in the rows of R represents differential stability of the "objects" or variables in the cultural space.[6] Metric multidimensional scaling is appropriate in this case, since the continuous ratio-scaled dissimilarities matrix is the requirement for optimal use of the metric procedures (Danes, 1975).

METHOD

The theory of measurement presents hypotheses suggesting that the procedures described above should be sufficiently precise (due to the continuous ratio-scaled measures) and reliable (due to averaging of component measures) to measure both stable patterns and small changes in a cultural configuration. Furthermore, it hypothesizes that attributes measured by traditional procedures can be accounted for as components of the cultural space derived by Galileo procedures. Accordingly, 29 graduate students and faculty members of a large sociology department were asked to estimate the pairwise dissimilarities among 19 professors in the department by the method of ratio judgments of separation. Following a brief paragraph of instructions in the use of the technique, respondents were given the standard: "If Professor Jones is 10 Galileos from Professor Smith, how far apart are ——— and ——— ?"

A Galileo is an arbitrary measure of distance between concepts. It provides respondents with a basis for estimating distances between concepts by whatever criteria they individually may choose to use. In this illustration, every possible non-redundant pair of the 19 professors in the depart-

TABLE I
Time Two Average Distances

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
A	0.0	9.75	11.07	9.41	9.72	10.24	8.21	10.61	11.90	15.59	10.08	10.76	9.11	11.10	4.35	9.46	13.00	5.79	12.14
B	9.75	0.0	6.92	8.37	8.21	9.11	7.15	9.96	12.21	18.54	10.54	12.57	11.78	13.67	10.96	10.33	17.30	8.57	10.15
C	11.07	6.92	0.0	9.92	5.77	10.85	8.19	3.92	13.08	18.04	11.88	14.96	12.35	11.81	10.87	11.50	17.58	9.18	10.69
D	9.41	8.37	9.92	0.0	7.07	8.21	7.85	9.27	16.10	15.79	11.76	14.28	12.89	12.54	10.52	6.70	16.62	12.78	10.59
E	9.72	8.21	5.77	7.07	0.0	9.96	9.30	9.56	24.76	22.45	12.85	15.69	12.44	15.96	12.54	11.93	22.90	11.39	13.70
F	10.24	9.11	10.85	8.21	9.96	0.0	7.18	8.96	11.25	14.86	9.56	14.32	12.11	13.82	10.62	10.89	14.68	8.87	11.93
G	8.21	7.15	8.19	7.85	9.30	7.18	0.0	8.26	8.93	16.52	11.00	12.73	10.69	14.50	11.59	10.96	17.12	9.00	11.04
H	10.61	9.96	3.92	9.27	9.56	8.96	8.26	0.0	11.54	14.62	11.42	16.04	13.04	15.15	11.41	10.15	18.46	10.19	11.81
I	11.90	12.21	13.08	16.10	24.76	11.25	8.93	11.54	0.0	14.75	10.19	7.38	10.04	15.25	12.62	11.82	14.38	10.36	12.89
J	15.59	18.54	18.04	15.79	22.45	14.86	16.52	14.62	14.75	0.0	11.48	13.52	14.44	13.11	11.12	11.57	10.33	14.48	13.64
K	10.08	10.54	11.88	11.76	12.85	9.56	11.00	11.42	10.19	11.48	0.0	9.96	9.76	9.56	9.04	9.64	11.23	10.18	9.56
L	10.76	12.57	14.96	14.28	15.69	14.32	12.73	16.04	7.38	13.52	9.96	0.0	8.63	9.29	10.29	11.89	9.45	10.13	12.82
M	9.11	11.78	12.35	12.89	12.44	12.11	10.69	13.04	10.04	14.44	9.76	8.63	0.0	9.43	10.50	12.11	16.25	8.59	11.32
N	11.10	13.67	11.81	12.54	15.96	13.82	14.50	15.15	15.25	13.11	9.56	9.29	9.43	0.0	7.40	9.07	6.55	10.30	9.29
O	4.35	10.96	10.87	10.52	12.54	10.62	11.59	11.41	12.62	11.12	9.04	10.29	10.50	7.40	0.0	7.60	9.46	5.50	8.28
P	9.46	10.33	11.50	6.70	11.93	10.89	10.96	10.15	11.82	11.57	9.64	11.89	12.11	9.07	7.60	0.0	11.71	9.13	9.26
Q	13.00	17.30	17.58	16.62	22.90	14.68	17.12	18.46	14.38	10.33	11.23	9.45	16.25	6.55	9.46	11.71	0.0	14.17	14.11
R	5.79	5.87	9.18	12.78	11.39	8.87	9.00	10.19	10.36	14.48	10.18	10.13	8.59	10.30	5.50	9.13	14.17	0.0	9.00
S	12.14	10.15	10.69	10.59	13.70	11.93	11.04	11.81	12.89	13.64	9.56	12.82	11.32	9.29	8.28	9.26	14.11	9.00	0.0

ment was listed for a separation judgment. The estimates for each pair were then averaged across all respondents to produce a square symmetric matrix S of the same order as the number of objects scaled. This matrix gives us the average separation between the group's perceptions of any two professors in the set and represents the measured values of the matrix S discussed earlier.

Table 1 contains the distances for the second measurement. Each successive row (and corresponding column) represents a different professor. The distance between any professor and himself or herself is zero by definition, and therefore zeroes occupy the main diagonal. The off-diagonal elements state the distances between different professors. Professor E has an average distance of 22 Galileos, for example, from Professor J. This magnitude is one of the largest in the matrix and extends between one man known as quite liberal and another thought to be conservative. Professor J is somewhat more quantitative in his work than E. The average distance between Professors P and R, on the other hand, is nine Galileos. Both are rural sociologists of moderate political stance. The work of both is moderately quantitative.

Following this task, the same respondents were asked to judge the same professors along two attributes generally considered important among sociologists: personal political position and style of professional research. The respondents were asked, "What is your estimate of the political position of these people?" and "To what degree do you think the work of these people tends to be quantitative and mathematical?" Each question was followed by a list of 19 professors who had been in the department at least one year. Each name was followed by response alternatives ranging from 0 (political left) to 0 (political right) in the first question, and from 0 (not quantitative at all) to 9 (highly quantitative) in the second. The respondents' ratings were averaged to yield a mean political and a mean quantitative rating for each professor.

Our sample, matched at three points in time, contains 24 students and five faculty members in a Midwestern sociology department. Four of these five were assistant professors; the fifth held associate rank. The faculty sample consisted of four men and one woman, while the student sample involved 19 men and five women. Seven of the students were in their first year of graduate school; seven were in their second year; six were in their third year; and four were in their fourth year. The mean number of weeks between the first and second administration was 16.2. That between the second and third was 6.3.

Stability and Change

Since 25% of the sample were in their first year of attendance, and since the initial sample took place in the first semester of residence, some substantial changes in these scores should be anticipated across the three time periods. The stability of the resulting configuration can be estimated in several ways. First, we may examine the difference among the three matrices directly by computing the average correlation of the corresponding cell entries across the three time periods. These correlations are derived by first arraying the distances in the three square, symmetric matrices, one for each time. The upper triangle is deleted since its elements duplicate those in the lower one. The main diagonal also is deleted because its elements are zeroes. In the next step each triangle is arranged into a single column by stacking the second column (having 17 elements) below the first (having 18 elements). The third is placed below the second, the fourth below the third, and so on until the triangular matrix is emptied. This process produces three single column vectors each with 171 elements. These procedures show that the time two distances correlate .71 with those observed the first time, and also .71 with those observed the last time. The correlation between the first and third sets of observed distances is .65.

These results indicate, as expected, a fairly substantial amount of change in perceptions over time, but nonetheless indicate the persistence of the major structure across the academic year.

As might be expected, the ordinally scaled measures of political position and quantitativeness of research are not sufficiently sensitive to detect these changes. The political attribute scales correlate as

TABLE 2
Time Two Scalar Products

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
A	35.91																		
B	-2.06	55.05																	
C	-13.27	33.65	60.18																
D	3.47	22.32	10.72	59.66															
E	32.03	55.14	74.81	66.20	122.71														
F	-8.61	11.90	-2.84	21.98	37.60	51.76													
G	7.74	25.50	20.06	22.57	41.67	23.39	47.04												
H	-5.82	10.37	54.87	19.35	48.17	18.19	21.89	54.95											
I	-3.07	2.72	-5.63	-50.04	-195.37	12.39	33.47	15.70	99.57										
J	-30.49	-71.25	-59.57	-21.86	-117.58	-11.46	-39.89	-1.30	14.03	146.04									
K	-13.33	-8.48	-20.95	-19.80	-1.63	-.29	-17.45	-13.17	17.37	26.65	39.05								
L	-3.16	-14.72	-45.07	-35.31	-24.97	-39.90	-20.75	-59.36	59.33	18.44	9.32	73.54							
M	6.66	-11.66	-15.94	-23.05	14.11	-17.28	-3.46	-22.34	29.60	-1.11	2.08	29.71	60.36						
N	-10.38	-32.57	-6.32	-15.44	-32.77	-36.32	-48.30	-49.04	-33.19	20.43	7.13	26.96	19.03	66.61					
O	22.04	-18.98	-15.45	-11.97	-3.76	-17.03	-30.12	-19.07	-16.38	24.73	-7.83	-2.66	-11.41	19.46	27.07				
P	-8.71	-7.74	-17.91	25.46	8.32	-15.33	-18.44	-.96	-1.89	24.20	-8.52	-15.84	-25.04	10.28	2.27	36.24			
Q	2.57	-56.45	-55.27	-39.18	-131.67	-12.74	-53.82	-68.83	15.52	88.75	25.57	61.25	-32.73	80.96	37.85	18.63	138.23		
R	16.49	3.50	3.25	-36.56	11.79	1.86	-1.66	-4.23	11.39	-16.47	-17.00	.77	8.59	-4.47	13.72	-8.25	-16.02	30.63	
S	-28.01	3.79	.69	1.48	-4.79	-17.48	-9.64	-9.48	-5.52	7.71	1.58	-17.59	-6.14	17.94	7.02	3.01	-2.63	2.57	35.51

TABLE 3
Time Two Principal Axes

	I	II	III
A	-1.15	-.60	-2.61
B	-5.18	2.16	-1.53
C	-5.82	1.16	.46
D	-4.76	-7.37	3.34
E	-12.33	-5.56	-1.80
F	-2.66	1.93	2.82
G	-4.22	4.43	.23
H	-4.83	3.25	5.06
I	6.02	10.61	-.60
J	9.02	-1.49	6.49
K	2.10	-.27	.10
L	5.27	.55	-5.93
M	.51	1.36	-5.13
N	4.35	-5.57	-2.51
O	2.03	-3.18	-.18
P	.76	-2.26	2.91
Q	10.81	-3.84	.44
R	-.52	.99	-2.55
S	.40	-1.30	.98

follows: time one with time two, .97; time two with time three, .98; and time one with time three, .98. The quantitativeness attribute scales correlate as follows: time one with time two, .99; time two with time three, .99; and time one with time three, .99.

Some investigators might suggest that these data show, to the contrary, that the moderate correlations among the ratio-scaled pair-comparison estimates indicate unreliability of measurement rather than change over time, while the very high correlations among the ordinally scaled attributes represent the reliability typical of a superior measurement system. We prefer our own interpretation for several reasons. First, the ratio-scaled pair comparisons represent values *averaged over 29 respondents*, hence a very considerable portion of the random (unreliability) component has been averaged out of these figures. Since substantive correlations as high as .8 and .9 have been reported on *single cases* of such measures (Marlier, 1974), it is extremely unlikely that measures averaged over 29 cases could be so unreliable. Second, there is excellent theoretical reason to believe changes like those observed here are highly probable in the phenomenon, since such a high proportion (25%) of the sample had only been members of the department a few weeks, and many had not even met a majority of the professors rated by the time of the first measurement. Furthermore, focused interviews with the respondents indicate substantial changes of opinion across the span of the research. Finally, these data were taken during a period of relatively unstable national and local political conditions, and many of those involved, both as subjects and objects of the scaling, experienced considerable and sometimes dramatic changes in their own political views. In general, the period of the research represented a time of substantial change for the department as a whole.

More precise information about the patterning of the changes observed can be obtained by the orthogonal decomposition procedure. The first step in this procedure is to recover the spatial configuration defined by S in a convenient form. This is accomplished by an orthogonal decomposition of the scalar products of S (adjusted so that the origin of the space is coincident with the centroid of the configuration following Torgerson, 1958; Woelfel, 1973; Serota, 1974). Torgerson's (1958, p. 254) formula moves the origin to the centroid and is the procedure usually used. Table 2 contains the scalar products for the distances in Table 1. (Since this matrix is also square symmetric, only the lower triangle is presented.) The element for each professor on the main diagonal contains the squared length of the vector from the centroid to that professor's perceived position. Professor J, who has the largest such element (146), participated in a sit-down demonstration. While Professor E is the third farthest from the centroid, Professors P and R are among the closest to it.

From each symmetric scalar products matrix are derived principal axes. We retained the three largest axes (Tatsuoka, 1971, p. 247) as the solution for each measurement.[7] Each solution accounts for more than 80 percent of the variance in its respective scalar products matrix. These axes (Torgerson, 1958) also constitute (X, Y, Z) coordinates if one wished to plot the positions of the objects in three dimensional space. Table 3, for example, contains the coordinates of the objects in Table 2. While Professor E has a −12 on the first axis, Professor J has a +9. On the second axis their coordinates are −6 and −1 respectively. The coordinates of Professor P and R, however, show them to be much closer together. Since their coordinates have relatively small absolute values, the positions of both are near the center of the configuration.

Rotating time one onto time two and time three onto time two produces a joint space, having an origin common to the objects at all three times as well as a common metric among them (Torgerson, 1972). Between time one and time two the coordinates on the first two dimensions correlate .86, those on the two second dimensions .51, and those on the two third dimensions .62. Between time two and time three the first dimensions correlate .82, the second .41, and the third dimensions correlate .44. Between time one and time three the first dimensions correlate .75, the second .26, and the third .07. The correlations both between the distances and among the coordinates suggest that the configuration persists to some extent through time. Generally, the social psychologists were grouped fairly close together, those interested in social organization and social change also were reasonably close together, as were the criminology and sociology of law people.

Attributes in the Multidimensional Space R

If the "equivalence hypothesis" tested here is correct, the space R resulting from the procedures described should be the space within which the attribute vectors used by respondents to differentiate the faculty are arrayed. Several procedures might be used to test this hypothesis. First, we might assume that the columns (factors) of R correspond directly to the unmeasured attributes, and therefore measure the zero-order correlations between the average attribute vectors and the factors. This is unlikely in general and impossible in this situation, since: (1) the column vectors of R are orthogonal by definition; i.e., the matrix Φ, which represents the matrix of intercorrelations among the factors, is constrained by the decomposition algorithm such that $\Phi = I$, and (2) in general, the attributes used in distinguishing cultural objects are seldom, if ever, independent of each other. In this study, for example, at time one the political attribute correlates with the quantitativeness attribute $-.43$, at time two $-.42$, and at time three $-.49$. These correlations correspond to angles of 115°, 115°, and 119°.

A second procedure might well be to relax the constraint that $\Phi = I$, thereby allowing the axes of R to lie at oblique angles to each other. This is, in general, not a fruitful procedure, however, since the statistical and mathematical difficulties of describing process across non-orthogonal coordinate systems are extremely cumbersome.

Fortunately, however, finding the projection of a vector or a set of vectors on a multidimensional vector space is the classic multiple regression model, and so an optimal test of the hypothesis in this instance consists in the goodness of fit of two regression equations to the data:

$$P = b_1F_1 + b_2F_2 + b_3F_3 + u$$

$$Q = b'_1F_1 + b'_2F_2 + b'_3F_3 + v$$

where

P = The 19 x 1 vector of mean political positions

Q = The 19 x 1 vector of mean quantitative scores

F_i = The ith column or axis of F

b_i, b'_i = The set of unstandardized regression coefficients or partial slopes of P and Q

u, v = stochastic (error) terms

The results of this analysis show that both attributes are clearly represented in R. At time one the multiple correlation between the political attribute and the first three axes of R is .91, at time two .93, and at time three .92. The fit of the quantitative research attribute is also good, with a multiple correlation at time one of .80, .79 at time two, and .75 at time three.[a]

While the multiple correlations clearly show that the political and quantitativeness attributes lie in the space R across all time periods, the pattern of unstandardized regression coefficients in Table 4 indicates further that the orientation of these vectors in R remains very stable across time. For both the political and quantitativeness dimensions almost all of the corresponding unstandardized regression coefficients remain similar in size and sign. There are a few changes, as on the third predictor of political stance between the first and second measurements. Some isolated changes, which we have made no effort here to predict, are to be expected,

TABLE 4
Unstandardized Regression Coefficients from Multiple Regression of Qualitative Position Upon Perceived Position

	Axis		Time One	Time Two	Time Three
Political Judgments	1		-.16	-.20	-.13
	2		-.02	-.07	.02
	3		.07	-.11	-.05
		R=	.91	.93	.92
Quantitativeness Judgments	1		.11	.19	.15
	2		.27	.16	.11
	3		-.27	-.28	-.06
		R=	.80	.79	.75

$p < .01$, one-tailed

but in general, these results suggest very clearly that the overall configuration given by R is quite stable, with the attributes themselves remaining relatively unchanged while some adjustments of the locations of individual professors take place.

CONCLUSIONS

Given the pattern of findings presented above, it is reasonable to conclude, under the conditions of the present research, that the Galileo procedures produce a stable and precise measurement system which is equivalent to very extensive applications of the best of conventional measurement systems. While this equivalence may seem to obviate the need for such a new system, in practice the conventional scaling procedures required to yield the precision, reliability, and wealth of information made available rather simply by the Galileo system of measurement would be very tedious, and would require information social scientists are very unlikely to possess for some time yet to come.

Not only do these procedures yield more precise measures, but the complete pair-comparisons form of the data allows for very simple and graphic analysis schemes, like the orthogonal reference frame R. The specification of a reference frame is an important first step in any scientific analysis (Halliday & Resnick, 1966), and R's orthogonal property makes it very convenient in such a role. Motions in the space (i.e., changes in relative meaning of the concepts scaled) can be decomposed along the orthogonal reference vectors, so that velocity and acceleration are given by

$$[illegible]$$

$$[illegible]$$

These equations provide very accurate descriptions of attitude and belief changes, since change of meaning is by definition given by motion in the space R. Results given here and elsewhere show clearly that the Galileo system yields data sufficiently stable and precise to warrant such analyses. The primary merit of the system, therefore, might be its ability to allow the formulation of attitude and belief change theories in the form of equations in mechanics (Woelfel, Saltiel, McPhee, Danes, Cody, Barnett & Serota, 1975).

In practice, this system provides a particularly useful means of arraying aggregate belief systems and processes on a convenient reference frame and is therefore very useful in the analysis of collective activities like elections, the spread of products and innovations, organizational decision making, and other group or cultural processes (Woelfel et al., 1975), since motions in any of the directions of the multidimensional space can easily be observed, even if an attribute arrayed in that direction has not been identified or measured. Galileo is particularly useful in "effects of" studies (such as the effects of an innovation, etc.), especially when one has little idea in advance of what such effects might be.

It goes without saying, of course, that the Galileo system is not meant as a tool to be used thoughtlessly in every circumstance, but by the same token it has shown applicability in many widely different scientific and commercial research contexts. What role it will play in the future development of communication theory and method rests largely on the outcomes of future research. Nonetheless, even in its elementary state of development, it has shown sufficient stability, precision, and ease of administration and analysis to warrant careful investigation by communication scientists.

NOTES

1. The term "Galileo System" refers not to a specific measurement or analysis technique, but rather to a set of theoretical measurement and analysis procedures taken collectively. Most of the specific procedures in the system (e.g., metric multidimensional scaling) were developed earlier by others (cf., Jacobi, 1846; Torgerson, 1958). Used in the Galileo System configuration these procedures provide particularly accurate measurement and convenient analyses for certain classes of communication problems. Because the unit of measurement used in early studies was frequently referred to as a *galileo*—e.g., "how many galileos apart are . . ."—the system of procedures is usually informally referred to as the "Galileo System."
2. While the choice of the unit of measurement is arbitrary, choice of different standards will have consequences for the patterns of measurements made with the system. Choosing as a criterion pair some ordinary language symbols whose relation to each other and other symbols is stable over time might make results of the measurement more clearly interpretable in terms of the ordinary language system than would a pair defined by symbols whose meanings fluctuate in the vernacular system. Good scaling practice, moreover, suggests a standard midway between the largest and smallest discrepancies likely to be encountered, so that judgments of extremely large or extremely small discrepancies are minimized. The logic of these procedures dates from antiquity. It is discussed clearly in Einstein (1961) and formally in Krantz et al. (1971).
3. To be sure, this matrix S is the result of a fairly elaborate measurement procedure, requiring $N(N-1)/2$ ratio-scaled pair-comparisons for any N objects, and the researcher might well wonder whether the result justifies the effort. Principally, the answer lies in the fact that the matrix S represents the differences among all $N(N-1)/2$ pairs of N objects across *all attributes along which the subject recognizes differences, regardless of how numerous those attributes may be*. This is true even where the number of attributes along which the objects are differentiated (N_A) exceeds the number of objects ($N_A > N$) or even the number of pairs of objects ($N_A > N(N-1)/2$). Thus, the $N(N-1)/2$ pair comparisons in fact produces a complete picture with (in general) far fewer measurements than would be required by traditional methods. As an example of how much effort is saved by these procedures, the matrix S could be estimated by traditional procedures as follows: (a) By some method—perhaps focused in-depth interviews—all N_A attributes upon which the subject is able to discriminate the $N(N-1)/2$ pairs of stimuli would be determined. (b) Ratio-level scales for *each* of these attributes would be constructed. (c) All N stimuli would be scaled by the respondent(s) on all N_A scales. (d) The resulting $N \times N_A$ matrix X would be postmultiplied by its transpose to yield the $N \times N$ matrix of scalar products B. (e) The matrix B would be completely factored to yield the $N \times N-1$ matrix F. (f) Estimates of the elements of S would be generated by the scalar equation:

$$S_{ij} = \left[\sum_{k=1}^{n-1} (f_{ik} - f_{jk})^2 \right]^{1/2}$$

(g) This work would then be repeated for each of the subjects in the sample. Finally, the estimates of any cell S_{ij} will be inaccurate to the extent that the procedures of step (a) above failed to identify all the attributes the subject uses when making pairwise discriminations among the N stimuli, and properly *weight* the *extent* to which each attribute enters into the subjects' judgment.
4. As N grows small, this expression will not, in general, provide a robust/resistant estimate of the population mean, and appropriate statistical procedures for smoothing small sample means are typically employed (Cody, 1976; Wainer & Thissen, 1976).
5. It is precisely the fact that this "cultural aggregate matrix" cannot be expected to conform to the psychological structures or processes of any individual (i.e. there is no "average person") that has led psychometricians to reject the averaging process and turn instead to non-metric and/or "individual differences" models. Clearly, attributes utilized by some individuals will not be utilized by others, and consequently the rank of the matrix S will in general be greater than the rank of any of the individual matrices from which it is averaged. This, however, is precisely what is wanted in a cultural measure, since, as Durkheim suggests, "The resultant surpasses the individual as the whole the part . . . No doubt each individual contains a part, but the whole is found in no one." While the average matrix S may or may not be inappropriate for psychological study, therefore, it is nevertheless precisely what is needed for cultural work.
6. These parameters depend as well on the choice of a suitable rotation procedure, which has been defined elsewhere (Woelfel et al., 1975).
7. The orthogonal decomposition procedure can, and usually does, yield $r = n-1$ roots for n concepts. Some of these roots are numerically quite small, and would be eliminated by normal procedures such as the Scree Test. While small, however, these vectors have been found in some cases to correlate very highly with measurable attributes (Barnett, 1975), and so cannot always be assumed to be simple unreliability or random error. The three roots we have retained here are sufficient for the general purposes of this analysis, however. See Barnett and Woelfel (1976).
8. Canonical correlations were calculated within each time relating the three axes of R to the two attributes. In all three time periods the canonical correlations were about equal to the corresponding multiple correlations, as should be expected.

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EXPLOITING PRAGMATIC RULES: DEVIOUS MESSAGES

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Consideration of the relationship between semantics and pragmatics leads to a formal analysis of pragmatic implications customarily made by auditors in this culture. The analysis isolates four types of responses to yes-no demand questions: (1) explication, (2) propositional implication, (3) relational implication, and (4) transparent question. It further shows how the latter three types can be exploited by devious communicators and proposes some possible social extensions of the system.

In the recent past, strong interest has developed in devising grammatical or rule-system approaches to the study of human communication. Sanders (1973) and Cushman and Whiting (1972) have made some intriguing and appealing arguments concerning the potential value of considering symbolic interactions as the manifestations of generally understood systems of rules. More recently, Nofsinger (1974, 1975, 1976)[1] and Simmons (1974) have applied such an approach to specific subsets of interactions with considerable descriptive and explanatory gain. Such discussions and applications are intuitively appealing. Making an analogy between communicative behavior and gameplaying behavior involves no strain. All communicators, like all gameplayers, are required to know the explicit rules—the types of behavior that are permitted and the types that are prohibited. For communicators, these are the rules of *syntactics* and *semantics*. To play the game of communication at all, a player must be able to encode in the symbol system. What distinguishes better players from worse ones is the ability to apply a set of implicit rules for success—strategic or *pragmatic* rules. Better players are more able to devise and apply a rule system for instrumental success within the rule system of required and prohibited behavior.

Our analysis, like Nofsinger's (1974), will consider a specific class of symbolic transactions, where the demander (D) places the respondent (R) in a position where the explicit fulfillment of the communicative demand would be "Yes" or "No." We will suggest a method by which such transactions might be explicitly modeled, discuss the means by which a respondent might exploit the pragmatic system to mislead the demander without actually lying (employ "devious messages"), and propose some possible applications and extensions of the system.

Throughout the paper, we will use the term "semantic level" to refer to the literal, explicit meaning of an utterance, and the term "pragmatic level" to refer to the implications by which the utterance is taken as a fulfillment of the communicative demand. It should be noted that our analysis depends heavily on Grice's (1975, p. 45) "cooperative principle," a principle asserting that communicators make a tacit agreement to say only relevant things. This principle implies that, in our system, demanders must be assumed to demand only what is relevant to them and respondents must be assumed to respond with only what is relevant to the demands placed upon them. Hence, we will not be concerned with situations where R asserts his inability to fulfill the demand ("I don't know") or his unwillingness to fulfill the demand ("I won't answer"). Likewise, we will not be concerned with situations where R asserts that D's demand is not relevant to R's and D's mutual interests ("None of your business").