Vol. 3 No. 4 Summer 1977

LIMITING THE SCOPE OF THE SPACIAL MODEL OF COMMUNICATION EFFECTS[1]

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An experiment tested the hypothesis that cognitive change resulting from information inputs can be represented as linear motion of concepts in multidimensional space. The theoretical background is reviewed and the mathematical derivation of the hypothesis is given. A set of 15 nations was scaled using Woelfel's Galileo system of multidimensional scaling. Experimental messages were introduced and the posttest interconcept distances compared with those predicted by theory. The crucial partial correlations were low, a failure to confirm the hypothesis. Secondary analyses suggested that the failure may have resulted from inadequate control of message content and failure to ensure that the concepts scaled compose a cognitive domain. The theory made better predictions for a subset of the concepts that might be a domain.

An experiment was conducted to test the hypothesis that cognitive change resulting from information inputs can be represented as linear motion of concepts in a multidimensional space. This research may be considered as an attempt to extend the bounds of the spacial model of cognition, a paradigm increasingly influential on communication research; the results may be considered as evidence of limits to the model's scope. The following sections will discuss the theoretical background of the research and present the derivation of the experimental hypothesis, describe the design, procedures, and analysis of the study, present the results, and consider alternative explanations.

THEORETICAL BACKGROUND

The Spacial Model

The concept of "cognitive space" has become widely influential in the social sciences. The term is often used as a vague allusion or metaphor, but it becomes unambiguous when tied to the operations of multivariate procedures such as factor analysis and multidimensional scaling.

Several lines of research during more than two decades have established that many conceptual structures can be represented as configurations of points (concepts) in a multidimensional space. The work of Osgood and associates (1957, 1974) is one of the earliest and longest lived, and is perhaps the best known of these projects. Osgood introduces the idea of *semantic space* as a model of the affective meaning system: a coordinate system whose origin is the point of neutral meaning and whose axes are the general factors of a set of bipolar attributes. Studies of a wide variety of concepts involving thousands of people in many countries have found that the major dimensions of the semantic space are evaluation, potency, and activity. We tend to assign connotative meanings to concepts along dimensions of good-bad, strong-weak, and active-passive. Thus, conceptual structures of a certain kind can be represented as arrays of points in the three-dimensional space defined by the three general factors.

A broader spacial model is found in the psychometric literature on multidimensional scaling (Torgerson, 1958; Shepard, Romney & Nerlove, 1972). Here computational procedures are used to convert matrices of psychological distance or similarity among concepts into configurations of points within spacial coordinate systems. The recent nonmetric scaling techniques are usually designed to produce a space of minimum dimensionality and maximum interpretability. The dimensions derived from multidimensional scaling research sometimes resemble Osgood's three factors and sometimes not, indicating the greater generality of the scaling model. Thus diseases seem to be conceptualized in terms of seriousness and contagion (D'Andrade, Quinn, Nerlove & Romney, 1972), while nations are discriminated according to their political alignment and economic development (Wish, Deutsch & Biener, 1972). This literature further demonstrates the feasibility of the spacial representation of cognitive structures.

Multidimensional scaling studies have also demonstrated relations between psychological distance and other human behaviors. For example, substitution patterns among political candidates (Mauser, 1972) and among consumer products (Stefflre, 1972) can be predicted from their locations in cognitive space; products or candidates that are psychologically closer are more likely to be substituted (switched among) by consumers or voters. In a similar vein, Jones and Young (1972) showed that communication patterns within a social system can be predicted from the locations of people in the cognitive spaces of group members.

In sum, both semantic space and nonmetric multidimensional scaling research tend to confirm the utility of a spacial model of cognition, in that those studies have shown that the spacial representation is stable, valid on its face, and related to other human behaviors.

Generalization of the Model

We may well wonder, in view of its success as a model of cognitive structure, just how far the spacial model can be generalized; how wide is the model's potential scope. One very tempting sort of generalization is to a model of cognitive change as *motion*. If a cognitive structure can be represented as a configuration of points in multidimensional space, can cognitive changes be represented as movements of concepts within that space?

Woelfel (1974), and his associates (e.g., Danes & Woelfel, 1975; Barnett, Serota & Taylor, 1976) have proposed a variation which explicitly permits and encourages the generalization of the spacial model to encompass motion. Woelfel's model assumes that the aggregation of all respects in which two objects of thought differ underlies an overall dissimilarity or psychological distance between the two objects. In contrast to Osgood's model, Woelfel's does not assume an attribute space spanned by fundamental factors. The dimensions of cognitive space may exhibit interpretable patterns (dimensions, clusters, or other forms) or the configuration of concepts may not be at all interpretable. In any case the configuration "is" just what it "is." In contrast to the nonmetric scaling model, Woelfel's does not assume that the validity of a representation rests on its simplicity, in terms of either its dimensionality or its interpretability.

What is of key importance to Woelfel is not the interpretability of cognitive space but its dynamics. Change in the meaning of an object can be represented as *movement* of the object relative to other objects. The crucial test of Woelfel's model is whether *laws of motion* can be found which parsimoniously account for the changes over time in cognitive space. If such laws cannot be found, or if more parsimonious laws can be found in another paradigm, then the model fails.

Because the relationships it displays can be assumed, even in principle, to be merely ordinal, nonmetric multidimensional scaling may be considered unsuitable for the investigation of motion in cognitive space. Thus, their interest in the study of change has motivated the renewed interest of Woelfel and his associates in the classical or metric approach, which makes stronger assumptions about measurement. This revived interest has led to the development of the Galileo system—a set of measurement and design techniques and a package of computer programs—which adapts classical multidimensional scaling to Woelfel's interest in the study of cultural processes.

The Galileo system has been described in detail by Serota (1974) and overviewed by Barnett, Serota & Taylor (1976). Essentially, the measurement procedure has the subject make an absolute (apparently ratio scale) judgment of the dissimilarity of every possible pair in a set of concepts. The interconcept distance matrix, aggregated across subjects, is transformed and factored to produce a matrix of coordinates for the concepts on a set of orthogonal dimensions. Unlike nonmetric multidimensional scales, this metric space exactly reproduces the distances among the concepts. (The price of this metric property is typically a more complex coordinate system than would be obtained by a nonmetric procedure.) In the study of cognitive change, data may be collected at several points in time. The Galileo system permits rotation of several spaces to a least-squares best fit and simultaneous plotting of several data sets in a single coordinate system. The rotation procedure is capable of taking account of theoretical assumptions about which concepts have and have not "moved" during the interval between measurements (Woelfel, Saltiel, McPhee, Danes, Cody, Barnett & Serota, 1975).

Several methodological studies (Barnett, 1972; Danes & Woelfel, 1975; Woelfel et al., 1975; Gordon, 1976; Gordon & DeLeo, 1976) have demonstrated the reliability and validity of the Galileo system for sufficiently large sample sizes. The main disadvantages of the Galileo system are the usual great complexity of the multidimensional space and the impracticality, for measurement reasons, of representing the cognitive structures of individual subjects. The overriding advantage is that only metric assumptions permit the study of cognitive change as motion.

The Empirical Evidence for Cognitive Motion

Several studies of Woelfel's model have been claimed to demonstrate meaningful cognitive motion. Gillham (1972), Barnett, Serota, and Taylor (1974, 1976), and Woelfel et al. (1975) all report studies in which obtained changes in the locations of concepts generally were successfully interpreted in light of known information inputs. These studies, however, share some important shortcomings. First, despite the purported precision of the model, the interpretative analysis in all cases was largely qualitative and in two of the studies was entirely post hoc, while in the other two studies it was based on qualitative predictions. Second, in every case the analysis focused on certain changes and ignored others. There seem to have been few attempts made to systematically explain all observed changes, to seek out evidence contrary to theory, or even to account for apparent anomalies.

The recent study of Barnett, Serota, and Taylor (1976) is illustrative. This was a trend study of motion of cognitions of candidates, parties, and issues in a U.S. Congressional election in which the authors apparently had some influence on the Democratic candidate's strategies. The results of the study are quite impressive, especially since the authors were able to predict an "indirect" change in distance between concepts on the basis of commonsense assumptions about how objects move in space. As the Democratic candidate worked to identify himself with "crime prevention" and the "Democratic party" he not only converged with those two concepts but also converged with "me" (the voter). Movement toward "me" was predicted as the resultant vector of the other two changes and was seen as an indirect, but planned consequence of the candidate's campaign strategy. Note, however, that this prediction involved only three of the 10 concepts studied.[2] If the candidate's movement toward "crime prevention" affects his distance from "me," then it seems logically necessary that his distances from *all* other concepts would be affected in some systematic way. Thus, the logic of the spacial model requires that all of those changes be explained. That, of course, is a difficult goal to achieve in the noisy context of a political campaign, and the authors readily admit that only controlled experimentation permits a rigorous test of the mathematical theory.

The research reported here was designed to avoid the pitfalls of past studies by testing, under experimental controls, a quantitative, a priori hypothesis derived from explicit assumptions, and by incorporating in the test of the hypothesis *all* available information about motion in the cognitive space.

A Theory of Linear Motion

Suppose that cognitive change resulting from information inputs can be represented as linear motion in multidimensional space. This implies that change in a concept results in precisely predictable indirect changes in the psychological distances between that concept and all other concepts in cognitive space. The principle can be seen by imagining a number of objects arrayed on a table. Moving one of the objects toward or away from a second object changes the moved object's distance from all other objects in a precisely determined fashion. As applied to human cognition this may seem like a wild hypothesis, but it follows rigorously from a set of assumptions which are not in themselves implausible: a conceptual structure in cognitive space, and a message that is "about" the distance of a concept from some other concept. Linear motion is just the simplest kind of change that could occur under these assumptions (although it is not at all the simplest possible kind of cognitive change were cognition conceived in nonspacial terms).

To make numerical predictions we must make several further assumptions, the most important of which are those that connect the concept of message to the concept of cognitive motion: a theory of communication effects (Craig, 1975). For this study the theory chosen was Woelfel's Linear Force Aggregation Theory. Saltiel and Woelfel (1975) explicate the theory and summarize the supporting evidence. Danes, Hunter, and Woelfel (1976) report a more recent study in which an accumulated information model was found to predict belief change more accurately than did two alternative models. The evidence for the theory is hardly conclusive, however, and a look at behavioral research done from other theoretical perspectives—e.g., studies of the relation of message discrepancy to attitude change or of information integration in impression formation—would suggest that more complex theories are ultimately required. The focus here, however, is not on the exact shape of information processing curves but on testing the fundamental idea of cognitive motion, so the simplicity of the Linear Force Aggregation Theory is attractive. Furthermore, because the theory posits that attitudes are "made out of" accumulated messages, the theory provides a direct link, a linear relationship, between messages and cognitive structures.

The Theory of Linear Motion makes several assumptions beyond those of Linear Force Aggregation Theory. Those assumptions are apparent in the derivation which follows.

A Theory of Linear Motion: Scope Conditions

The theory predicts the time t' distances among a set of concepts (s'_{ij}) given the following:

1. The following quantities are known: the set of distances between each pair of concepts i and j at time t (s_{ij}), the projection of each concept on each dimension of cognitive space at t (f_{ik}), the inertial mass of each concept (n_i), the number of messages received in the interval $t - t'$ (p), and the set of assertions contained in messages received during the interval $t - t'$ ($\bar{s}_{ij}$).
2. The interval $t - t'$ is sufficient for equilibrium to be established in the cognitive space following receipt of messages.
3. No change occurs during the interval $t - t'$ except that induced by known messages.

Derivation of the General Structural Equation

Woelfel's Linear Force Aggregation Theory states that a belief is equal to the mean value of all messages received. Translated into terms of the spacial model,

$$s_{ij} = \frac{\sum_{k=1}^{n} s_{ijk},}{n} \tag{1}$$

where: s_{ij} = the psychological distance between concepts i and j; s_{ijk} = the distance proposed by message k; n = the total number of messages which have located i and j—the 'inertial mass' of s_{ij}. A direct implication is that the effect of new messages on an already established belief is equivalent to a change in a mean given additional values:

$$s'_{ij} = \frac{ns_{ij} + p\tilde{s}_{ij}}{n + p} = s_{ij} + \frac{p}{n + p} \cdot (\tilde{s}_{ij} - s_{ij}), \tag{2}$$

where: s'_{ij} = the new belief; p = the number of new messages; $\tilde{s}_{ij}$ = the mean distance proposed by the new messages. Since the effect of the new messages is not expressed as a function of time, we ought to regard s'_{ij} as an *equilibrium value* that will be approached as the messages are processed. In short, we are dealing here with what strictly might be called *comparative statics* rather than dynamics.

Assume that n, the total number of messages which have located i and j, can be expressed as a sum of two quantities,

$$n = n_i + n_j \tag{3}$$

where n_i and n_j are the number of messages which have located i and j, respectively. This assumption allows us to partition the expression on the right in Equation 2 so as to reflect the relationship between inertial mass and message effects:

$$s'_{ij} = s_{ij} + \left[\frac{n_i}{n} \cdot \frac{p}{n + p} \cdot (\tilde{s}_{ij} - s_{ij})\right] + \left[\frac{n_j}{n} \cdot \frac{p}{n + p} \cdot (\tilde{s}_{ij} - s_{ij})\right] \tag{4}$$

where the left bracketed expression is the change brought about in j and the right bracketed expression is the change brought about in i. The change brought about, that is, is inversely proportional to the number of messages which has located a concept. In still other words, the change brought about by new messages is "apportioned" between i and j in inverse proportion to their inertial masses.

Now assume that i and j are located in a multidimensional space, and our problem is to determine the change in location of a "moved" concept i with respect to all other concepts in the space. The first step is to note that s_{ij} can be expressed in terms of the projections of i and j on a set of orthogonal reference axes of the space:

$$s_{ij} = \sqrt{\sum_{k=1}^{r} (f_{ik} - f_{jk})^2}, \tag{5}$$

where f_{ik} and f_{jk} are the projections of i and j, respectively, on axis f, and r is the dimensionality of the space. Both $\tilde{s}_{ij}$ and s'_{ij} can, of course, be expressed similarly.

The general structural equation for postmessage pairwise distances among concepts in the space can now be derived in three steps. First, we need an expression for $\tilde{f}_{ik}$, the projection of concept i on axis f as proposed by new messages. Second, we need an expression for f'_{ik}, the new equilibrium for the projection of i on f brought about by the new messages. Third, we can write the general structural equation.

The expression for $\tilde{f}_{ik}$ assumes that one-half of the change *proposed* by $\tilde{s}_{ij}$ is directed toward concept i, and that the change proposed is apportioned among the dimensions of the space proportionate to the distance between the projections of i and j on the dimensions:

$$\tilde{f}_{ik} = f_{ik} + \frac{(f_{ik} - f_{jk})^2}{(s_{ij})^2} \cdot \frac{1}{2} \cdot (\tilde{s}_{ij} - s_{ij}) \cdot \frac{f_{ik} - f_{jk}}{|f_{ik} - f_{jk}|} \tag{6}$$

The last factor in expression (6) is needed to determine the sign of the changes proposed in f_{ik}. The expression for f'_{ik}, the postmessage equilibrium value of the projection of concept i on axis f, can now be adapted from the appropriate parts of Equation 4:

$$f'_{ik} = f_{ik} + \frac{2n_i}{n} \cdot \frac{p}{n + p} \cdot (\tilde{f}_{ik} - f_{ik}) \tag{7}$$

In Equation 7, n_i/n is multiplied by 2 to take account of the fact that the derivation of $\tilde{f}_{ij}$ has already divided the proposed change, and allocated the change to concepts i and j separately. Note that if either $p=0$ or $\tilde{s}_{ij}=s_{ij}$, then Equations 6 and 7 result in $f'_{ik}=f_{ik}$. These equations, that is, can be applied to any concept in the space, regardless of whether any messages have affected that concept.

Substitution into Equation 5 now gives the general structural equation:

$$s'_{ij} = \sqrt{\sum_{k=1}^{r} (f'_{ik} - f'_{jk})^2}, \quad (8)$$

where i and j are *any* two concepts in the space. Equation 8 is a general structural equation in the sense that it gives the postmessage distances between all pairs of concepts, including pairs in which neither, one or both concepts have been affected by messages.

METHOD

A pretest-treatment-posttest, within subjects experimental design was used. Ss were 64 graduate and undergraduate students in communication classes at Michigan State University.

Fifteen concepts were scaled. The concepts were nations selected by a procedure that combined random and judgmental features.

Three messages were constructed. Each message argued that a pair of nations was either very similar or very different. The messages were of comparable length and structure.[3]

In the pretest the 15 nations were scaled. The Ss made direct ratio judgments of the distances between all 105 pairs of concepts. They then read the messages, which were intended to induce motion in six concepts, leaving nine concepts unmoved. The two sets of concepts (manipulated and not) provided experimental control. The theory predicts that specific changes should have occurred in 69 of the 105 distances, while the remaining 36 distances should not have changed. The Ss also made estimates of the distances between manipulated concepts "in the message," those estimates to be used as estimates of the contents of the messages. The Ss also rated the familiarity of the countries. Those ratings were used to estimate the inertial masses of the concepts.

In the posttest (one week later) the Ss again read the three messages, then again estimated the 105 interconcept distances, which distances were to be compared with those predicted by theory.

Pretest and posttest distances were aggregated across Ss and the mean distance matrices were subjected to metric multidimensional scaling, the second space rotated to comparability with the first by two procedures described by Woelfel et al. (1975): (1) a "no stable concepts" rotation that assumes no real motion has taken place between measurements (least squares best fit of the coordinate matrices), and (2) a "stable concepts" rotation that assumes "real" motion by the six manipulated concepts but no others. Procedure 2 involves translating the coordinate matrices to the centroid of the stable (assumed unmoved) concepts before rotation.

A computer program (TESTLAW) was written to input the coordinate matrices and message content and inertial mass estimates and output interconcept distances and concept coordinate values as predicted by the theory of linear motion under several sets of auxiliary assumptions discussed below. These predicted values could then be compared with those actually observed.

The fundamental hypothesis test is a correlation coefficient between predicted and observed posttest interconcept distances among concepts. There are, however, many different bases upon which the correlation can be computed. First, two different rotation procedures were used to make the posttest space comparable to the pretest space. Each procedure yielded a unique set of observed posttest distances as computed from coordinate values by the Pythagorean Theorem. The actually observed distances are, of course, still a third set. Second, there are theoretical grounds for supposing that the distances between concepts on the *first few dimensions* of cognitive space are more valid than the raw distances, since the latter include more error. Thus the correlation may be computed on cumulative subsets of the dimensions of cognitive space. Third, since the effects of information, rather than the mere

TABLE 1
Pretest Mean Interconcept Distances *

		2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	China	72	164	232	154	146	112	129	184	187	166	181	110	172	163
2.	Singapore		152	174	140	157	118	102	166	159	154	148	168	151	139
3.	Mexico			95	109	159	155	156	150	72	143	133	181	149	142
4.	U.S.A.				160	181	186	188	101	130	192	160	163	207	189
5.	Portugal					103	142	149	125	106	153	106	135	159	142
6.	Poland						164	164	105	148	175	118	75	161	151
7.	India							125	158	151	144	133	166	133	145
8.	Fiji								174	157	146	156	208	167	143
9.	W. Germany									146	188	131	124	186	182
10.	Brazil										137	139	170	145	148
11.	Cen. Afr. Rep.											152	174	76	84
12.	Greece												140	158	162
13.	U.S.S.R.													201	203
14.	Congo														99
15.	Guyana														

* Standard of measure: "Italy and England are 100 units apart"

TABLE 2
Posttest Mean Interconcept Distances

		2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	China	112	183	197	166	151	138	156	178	181	173	165	127	168	170
2.	Singapore		124	155	146	177	129	96	159	151	166	161	159	169	152
3.	Mexico			109	111	154	158	151	149	88	147	145	180	165	147
4.	U.S.A.				157	154	176	169	101	123	181	152	138	197	162
5.	Portugal					122	150	148	119	76	138	105	136	163	162
6.	Poland						175	176	117	157	179	120	90	160	164
7.	India							122	169	153	147	137	154	134	127
8.	Fiji								160	145	153	164	185	165	125
9.	W. Germany									140	167	127	135	175	167
10.	Brazil										156	132	163	151	136
11.	Cen. Afr. Rep.											170	179	117	133
12.	Greece												134	153	167
13.	U.S.S.R.													178	189
14.	Congo														141
15.	Guyana														

TABLE 3
Pretest Coordinates—Stable Concepts Rotation

Dimensions \ Concepts	1	2	3	4	5	6	7	8
1	-74.9	-65.6	3.0	76.7	7.8	21.4	-63.3	-76.7
2	88.7	26.5	-73.6	-74.3	- 9.6	39.9	12.3	- 4.4
3	26.4	61.5	32.2	51.9	- 8.7	-49.0	29.4	73.8
4	-33.3	- 1.1	-24.2	-24.1	35.6	35.2	15.8	50.1
5	27.6	1.1	48.9	-29.6	60.9	19.8	-24.8	7.6
6	- 7.1	-18.6	2.0	-17.2	- 6.0	-42.9	52.4	-32.3
7	- 8.9	11.7	- 4.4	9.3	-10.2	-14.7	-37.1	10.1
8	- 3.2	-37.3	-16.9	- 7.9	-10.2	.9	3.4	38.5
9	.5	22.9	1.6	- 1.4	-22.4	16.5	-21.6	9.1
10	5.0	-30.7	24.8	- 6.2	-31.5	9.2	- 2.4	3.0
11	- 5.0	6.7	-10.9	5.0	-18.0	12.8	11.2	- 4.0
12	- .2	- .1	.0	.2	.0	.0	- .1	- .2
13	1.3	.2	.4	- 2.5	- 1.8	- 1.7	- 1.2	- 1.4
14	-17.1	13.2	9.9	-10.7	- 6.3	22.7	10.4	-16.1
15	44.2	-23.1	-33.8	31.9	2.7	12.8	-10.4	-22.4

Dimensions \ Concepts	9	10	11	12	13	14	15	Eigenvalues[7]
1	65.2	4.3	-85.3	11.0	46.2	-93.2	-87.3	56306.
2	- 1.3	-72.2	-54.3	-11.8	74.4	-55.3	-54.7	41254.
3	6.9	7.3	-43.4	-15.4	-38.9	-52.3	-26.7	24174.
4	25.0	- 6.9	-21.1	64.7	-38.1	1.5	10.3	14404.
5	-38.8	51.1	-10.5	5.7	1.8	-15.0	- .8	13308.
6	-26.4	8.5	- 3.1	40.1	2.3	5.2	-54.3	11726.
7	-30.9	-23.0	32.9	38.7	15.0	-27.5	- 4.1	7186.
8	4.7	25.2	27.8	-19.0	10.3	-15.2	-21.6	5944.
9	2.6	19.5	- 5.1	8.0	- 1.1	33.9	-28.9	4314.
10	-10.8	-22.1	-14.9	3.8	- 8.5	- 5.2	- 1.2	3655.
11	-15.2	22.9	- 8.9	5.8	5.1	-11.9	18.0	2202.
12	.1	.0	- .2	.0	.1	- .2	- .2	0.
13	3.1	1.4	.5	1.3	- 1.2	- 1.8	.8	- 37.
14	- 2.5	-10.7	20.8	-14.5	-19.0	-21.6	-18.6	- 3544.
15	-12.1	.5	9.2	8.1	-50.0	- 6.0	-15.3	- 8484.

TABLE 4
Posttest Coordinates—Stable Concepts Rotation

Dimensions \ Concepts	1	2	3	4	5	6	7	8
1	-60.9	-41.1	- 9.7	60.0	- 2.4	46.6	-70.9	-31.1
2	89.2	11.6	-73.2	-50.1	-19.5	41.8	.5	-10.4
3	23.1	67.6	53.3	38.7	-18.4	-23.5	9.8	16.2
4	-14.5	-36.6	-17.2	-34.8	-14.6	20.8	22.0	-35.6
5	- 1.6	10.7	36.4	- 6.1	- 7.3	38.5	-21.6	20.5
6	-11.2	31.6	- 5.4	- 9.2	29.9	-29.3	44.4	69.4
7	3.8	- 2.3	4.2	15.7	3.7	-17.3	-47.3	-45.3
8	.9	5.1	5.5	- 1.9	- 2.1	6.2	3.1	6.5
9	-14.5	-13.5	24.2	-33.1	71.9	34.5	-23.9	- 5.5
10	7.9	- 8.5	24.7	-16.2	32.7	.6	-13.0	-47.9
11	-29.3	-39.4	- 8.5	19.1	-15.1	3.2	24.1	-53.8
12	-11.0	23.0	- 3.1	- 1.6	11.0	- .5	- .8	- 8.5
13	.2	.0	- .2	- .2	- .1	.1	.0	- .1
14	- 8.5	13.4	-10.9	- 8.3	-21.4	16.3	5.9	- 8.0
15	5.0	7.9	-19.6	25.1	17.6	14.7	6.6	- 4.6

Dimensions \ Concepts	9	10	11	12	13	14	15	Eigenvalues[7]
1	68.9	-10.1	-73.1	17.6	21.5	-68.6	-43.4	45476.
2	-17.7	-53.1	-55.2	- 1.7	66.5	-26.7	-34.7	34007.
3	-15.2	27.5	-66.6	- 6.7	-12.9	-17.9	-13.9	24696.
4	-13.8	-17.4	-20.9	68.7	-10.4	57.8	- 8.1	15893.
5	-40.3	-17.7	11.2	- 8.0	- 8.6	- 7.1	28.9	12508.
6	- 7.8	10.3	-15.8	41.8	- 7.6	-39.7	- 5.8	10510.
7	-16.5	- 1.0	11.8	17.7	27.9	-15.2	-66.1	10215.
8	1.4	- 8.8	2.0	- 5.4	8.4	3.1	- 2.0	7516.
9	- 2.5	54.2	- 3.7	11.6	7.5	24.1	-37.4	6392.
10	3.5	- 5.1	-13.2	20.0	-14.3	-61.2	-23.9	4318.
11	-22.2	-20.1	-19.0	-13.1	45.8	-23.6	-39.6	2988.
12	2.8	- 2.0	- .1	3.0	11.4	5.7	14.3	1245.
13	- .1	- .2	- .1	.0	.2	- .0	- .1	0.
14	.4	20.3	12.0	.9	- 7.8	-12.4	- 8.3	- 2035.
15	-12.2	- 2.2	3.2	- 1.9	-21.0	3.7	- 4.0	- 2403.

stability of cognitive space, are at issue, the pretest distances should be controlled in the analysis. This may be done by computing partial correlations.

All of these tests were computed and are reported here. Additional correlations were computed and are not reported here. These involved the use of change scores and the prediction of coordinate values. The patterns of these correlations were deemed sufficiently similar to the reported correlations to warrant their exclusion.

RESULTS

The Multidimensional Scale

The pretest and posttest interconcept distance matrices are given in Tables 1 and 2. The results of the metric multidimensional scaling analysis (for the "stable concepts" rotation procedure only) are given in Tables 3 and 4 and in Figures 1 and 2.

FIGURE 1
X-Y Plane—Stable Concepts Rotation

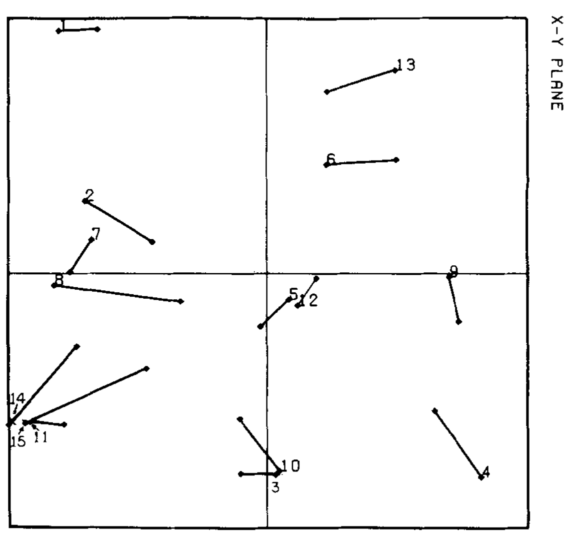

FIGURE 2
First Three Dimensions—Stable Concepts Rotation

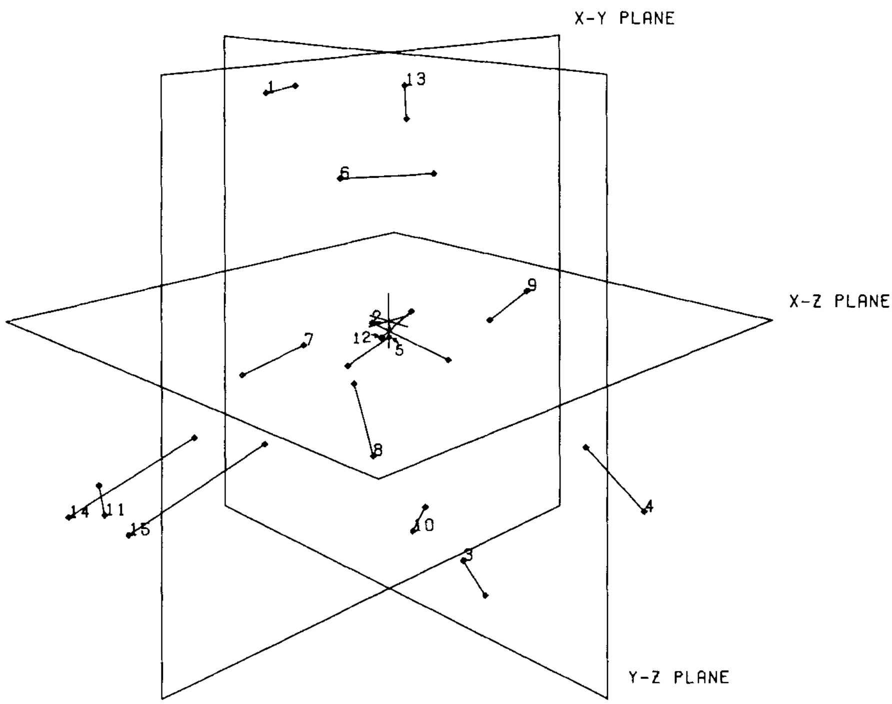

Table 3 is the coordinate matrix for the pretest data, while Table 4 is the rotated coordinate matrix for the posttest data. Fifteen roots were extracted from each distance matrix. This result would be theoretically impossible since n points can always be represented in n−1 or fewer dimensions. In each case, however, one dimension accounted for approximately none of the variance in the distance matrix. These coordinates, as Serota points out (1974, 64), "are artificial and represent rounding error in the computer algorithm."

Three of the valid roots extracted from the pretest matrix were negative, while two of the 14 valid posttest roots were negative.[4] The negative roots accounted for about 6.7 percent of the total pretest interconcept distances (the total of their eigenvalues was −11,553 as compared to a trace of 161,713 for the matrix). The negative roots accounted for about 2.7 percent of the total posttest interconcept distances (the total of their eigenvalues was −4397 as compared to a trace of 161,192 for the matrix). Similar shrinkage of the imaginary dimensions has been noted in previous studies (e.g., Barnett, Serota & Taylor, 1976).

Figures 1 and 2 are two- and three-dimensional plots of the results of the stable concepts rotation procedure. The figures show both pretest and posttest locations. The pretest locations of the nations are identified by the concept numbers and are connected by lines to the posttest locations. In Figure 1, X, the first dimension, is horizontal, and Y, the second dimension, is vertical. In Figure 2, X, the first dimension, runs from left "front" to right "rear"; Y, the second dimension, is vertical; Z, the third dimension, runs from right "front" to left "rear." The X and Y dimensions are readily interpretable as economic development and political ideology, respectively.[5] The first dimension runs from the United States and West Germany at the high end through moderately developed European and Latin American countries to the least developed African and Asian countries at the low end. The second dimension runs from China and U.S.S.R. at one end through various Asian and European countries to the American nations at the other end—a general, although not entirely consistent, trend from most radical to most conservative countries. These two dimensions are similar to the first two dimensions found in the nonmetric multidimensional scaling of nations by Wish et al. (1972).

The third dimension is not so readily interpretable (nor was it in the Wish et al. study). Regional clustering, however, is evident on the X-Z plane, with each quadrant corresponding roughly to a continental zone. The overall similarity of the scaling results to those obtained by Wish et al. tends to confirm the validity of the present scale.

The reliability of the scale may be assessed in at least two ways. One is to correlate the mean pretest interconcept distances with the corresponding posttest distances. The correlation for all distances (N=105) was .87; that for all unmanipulated distances (those hypothesized not to change, N=36) was .91; that for all manipulated distances (N=69) was .84; and that for indirectly changed distances (N=66) was .85. Note that the lower correlation for the indirectly changed distances than that for all distances is consistent with the conclusion that the messages had indirect effects as hypothesized.

A second way of assessing reliability is to examine the stability of the coordinate system by correlating the pretest coordinates with the posttest coordinates for each dimension. This approach, of course, may be strongly influenced by the rotation procedures employed. The reliabilities tend to be greatest for the dimensions having the largest absolute eigenvalues—the first few real dimensions (large positive eigenvalues) and the last few imaginary dimensions (large negative eigenvalues). These dimensions account for much of the variance in the space. For the no stable concepts rotation, the pretest-posttest correlations were .99, .98, and .95 for the first three (large positive eigenvalue) dimensions and .60 and .90 for the last two (large negative

TABLE 5
Pearson Correlation of Predicted with Obtained Posttest Interconcept Distances, Computed on Various Bases *

Distances Included in the Analysis	Dimensions Included in Computations	Predictor $A=\hat{s}m_{ij}$ $B=\hat{s}_{ij}$	s'_{ij} Comp. From No Stable Concepts Rotation	s'_{ij} Comp. From Stable Concepts Rotation	Actually Observed s'_{ij}
All (N-105)	1-15	A	.836	.866	.866
		B	.858	.885	.885
	1-12	A	.864	.880	.867
		B	.878	.895	.885
	1-9	A	.838	.798	.866
		B	.854	.816	.882
	1-6	A	.888	.718	.841
		B	.883	.722	.858
	1-3	A	.921	.764	.821
		B	.922	.765	.828
	1-2	A	.954	.852	.757
		B	.953	.858	.763
	1	A	.964	.837	.619
		B	.964	.838	.619
Unmanipulated Distances Only (N-36)	1-15	A	.862	.914	.914
		B	.862	.914	.914
	1-12	A	.887	.903	.889
		B	.887	.903	.889
	1-9	A	.845	.867	.881
		B	.845	.867	.881
	1-6	A	.878	.844	.857
		B	.878	.844	.857
	1-3	A	.918	.891	.806
		B	.918	.891	.806
	1-2	A	.933	.904	.814
		B	.933	.904	.814
	1	A	.949	.901	.594
		B	.949	.901	.594
All Manipulated Distances (N-69)	1-15	A	.824	.836	.836
		B	.862	.867	.867
	1-12	A	.859	.869	.858
		B	.885	.894	.887
	1-9	A	.843	.760	.864
		B	.870	.792	.890
	1-6	A	.891	.659	.847
		B	.898	.665	.872
	1-3	A	.925	.727	.831
		B	.928	.725	.843
	1-2	A	.964	.852	.736
		B	.963	.856	.746
	1	A	.973	.828	.631
		B	.973	.829	.631
Indirectly Changed Distances (N=66)	1-15	A	.826	.849	.849
		B	.837	.851	.851
	1-12	A	.860	.876	.870
		B	.861	.875	.869
	1-9	A	.836	.749	.874
		B	.844	.749	.873
	1-6	A	.876	.615	.855
		B	.877	.615	.860
	1-3	A	.919	.700	.856
		B	.919	.699	.856
	1-2	A	.963	.841	.765
		B	.960	.843	.762
	1	A	.972	.818	.616
		B	.972	.819	.616

* All correlations in this table are significant, $p<.001$, one-tailed test.

eigenvalue) dimensions. For the stable concepts rotation, the corresponding correlations were .99, .93, and .94 for the first three dimensions and .52 and .78 for the last two dimensions. The reliabilities seem adequate under both rotation procedures.

It can be noted, as an aside, that the fair stability of the imaginary dimensions tends to undermine interpretations of such dimensions as indicating measurement error. Whatever psychological meaning the imaginary dimensions may have, they are a stable phenomenon, not random error.

Hypothesis Tests

The mean of the absolute changes of the three *directly* changed distances was 25.8. The mean of the absolute changes of the 66 *indirectly* changed distances was 12.3. The mean of the absolute changes of the 36 *no change* distances was 10.8. This pattern is consistent with the hypothesis.

A more direct test is given by the correlation of predicted with observed posttest interconcept distances. As discussed above there were many distinct bases on which such a correlation might be computed. The results are presented in Tables 5 and 6.

In Table 5 are the zero-order Pearson correlations between the posttest interconcept distances (s'_{ij}) and those predicted by the theory, either including concept masses in the computations ($\hat{s}m_{ij}$) or excluding concept masses from the computations ($\hat{s}_{ij}$). All of the correlations (which, of course, were highly interdependent) were statistically highly significant. Most were greater than .80. Several general patterns in these correlations may be noted. First, for the no stable concepts rotation only there was a tendency for the correlations for the "computed" posttest distances to increase in magnitude as less dimensions were included in the computations. This would be expected since the larger (lower) dimensions are more stable. Why the stable concepts rotation did not fit the same pattern is unclear. The correlations for the actually observed posttest distances, however, fit an opposite pattern, yielding higher correlations for predictions based on more dimensions. This also would be expected, however, since the predictions based on only a few dimensions are not truly comparable to the actually observed posttest distances, which are, as it were, based on all dimensions. Second, different patterns resulted from the different rotation procedures. The stable concepts rotation displayed a pattern of higher correlations for unmanipulated distances than for manipulated distances. The no stable concepts rotation produced no such pattern. The pattern of correlations for the actually observed

TABLE 6
First Order Partial Correlation of Predicted with Obtained Interconcept Distances, Computed on Various Bases

Distances Included in the Analysis	Dimensions Included in Computations	Predictor $A=\hat{s}m_{ij}$ $B=\hat{s}_{ij}$	s'_{ij} Comp. From No Stable Concepts Rotation	s'_{ij} Comp. From Stable Concepts Rotation	Actually Observed s'_{ij}
All (N=105)	1-15	A	*** .346	*** .336	*** .336
		B	*** .358	*** .369	*** .370
	1-12	A	*** .317	*** .335	*** .331
		B	*** .330	*** .359	*** .360
	1-9	A	** .294	*** .308	*** .315
		B	*** .311	** .287	*** .341
	1-6	A	* .186	.069	*** .334
		B	* .200	.113	*** .356
	1-3	A	.142	.090	** .275
		B	.137	.070	** .256
	1-2	A	.017	• .201	* .194
		B	.015	* .216	* .180
	1	A	-.120	** .231	.060
		B	-.144	• .196	.032
All Manipulated Distances (N=69)	1-15	A	*** .444	*** .385	*** .385
		B	*** .455	*** .425	*** .425
	1-12	A	*** .414	*** .413	*** .412
		B	*** .425	*** .439	*** .444
	1-9	A	*** .388	*** .373	*** .402
		B	*** .405	** .353	*** .430
	1-6	A	* .238	.063	*** .420
		B	* .253	.121	*** .450
	1-3	A	• .207	.028	*** .373
		B	.196	.003	** .347
	1-2	A	.006	.166	* .261
		B	.050	.181	* .234
	1	A	- .171	* .262	.074
		B	*- .204	* .278	.040
Indirectly Changed Distances (N=66)	1-15	A	• .242	.150	.150
		B	• .249	.183	.183
	1-12	A	.171	.156	.149
		B	.179	.177	.173
	1-9	A	.204	.162	.137
		B	* .216	.111	.155
	1-6	A	.112	- .031	.165
		B	.126	.042	.187
	1-3	A	.114	.050	.082
		B	.105	.011	.052
	1-2	A	- .054	.101	.006
		B	- .004	.120	- .033
	1	A	- .153	* .268	- .035
		B	- .190	• .254	- .066

• $p<.05$, one-tailed test
** $p<.01$, one-tailed test
*** $p<.001$, one-tailed test

posttest distances was more similar to the stable concepts than to the no stable concepts rotation—a fact which may suggest the greater validity of the stable concepts procedure. Finally, there was no clear pattern of differences between correlations involving predictions taking account or not taking account of the concept masses. Thus inertial mass, as measured in the present study, did not clearly contribute to the theory's predictive power.

In Table 6 are the first order partial correlations controlling for the pretest interconcept distances. These correlations were substantially lower than the zero-order correlations, demonstrating that much of the accuracy of prediction displayed in Table 5 was due simply to the stability over time of the aggregate cognitive space, a stability rightly assumed by the theory. Two additional facts about this table are worth noting. First, several of the partials were large enough to be statistically significant, but the meaning of this is complicated by the interdependence of the correlations. Second, the correlations were lowest when restricted to the 66 indirect changes, although a few (including, however, none of those for the actually observed posttest distances) were still large enough to be significant.

DISCUSSION

Evaluation of Results

The results of this study do not strongly support the hypothesis. The correlation of predicted and observed interconcept distances showed that the theory predicts very well, but only because it predicts the general stability of the cognitive structure. When the pretest scores are statistically controlled, especially when the three direct changes are also removed from the analysis, the predictive power of the theory becomes quite poor in absolute terms: seldom does it account for as much as five percent of the variance in the dependent variable.

A closer examination of the plots of the results (Tables 1 and 2, and Figures 1 and 2) may shed some light. The three experimental messages argued that Singapore and Fiji are close, that Congo and Guyana are distant, and that Portugal and Brazil are close. Consider the actual changes of these countries. While the *net* change in each case was as predicted, the motion was not, as assumed by the theory, directly along the lines connecting the pairs. The slight net convergence of Singapore and Fiji resulted mostly from changes along dimensions not plotted. The two countries actually diverged on the first and third dimensions (in the latter case bypassing one another) and converged on the second dimension only because of Singapore's greater "velocity"; Fiji moved in the direction opposite to that predicted. Again, Congo and Guyana's net divergence resulted from movements at large angles to the directions predicted. Regardless of rotation procedure one of the most prominent changes was Congo's movement, contrary to prediction, along the second dimension. The divergence of the two nations on the third dimension was about as expected, but their lockstep motion on the first dimension was quite opposite to that predicted. Finally, Portugal and Brazil's net convergence occurred despite Brazil's movements opposite to predictions on the first and third dimensions and Portugal's opposite movement on the first and second dimensions. Net convergence on the second and third dimensions occurred only because the country moving in the "right" direction tended to overtake the other country.

There are evident in the plots other changes that are not interpretable in terms of the hypothesis. Several unmanipulated nations exhibited apparently substantial movements. One noticeable tendency was for the more extreme countries to move inwards in the general direction of the origin—a pattern suggestive of the phenomenon of regression toward the mean. These changes are not interpretable in terms of facts known to the investigator.

The results of this study are, in some respects, remarkably similar to those of Barnett, Serota, and Taylor (1976). Careful study of the plots from both studies gives one the impression that several sets of two or three concepts have moved "lawfully" with respect to each other, but not with respect to the space as a whole. The present study may lend quantitative confirmation to that impression. Since a high partial correlation could occur only if motion were lawful with respect to the *entire* cognitive space, the low partials may reflect motion which is regular only locally or among some subset of the concepts.

Alternative Explanations

Three alternative explanations of the results of this study deserve discussion. The first explanation is that the experiment failed because the spacial model is radically wrong. One alternative model would be a cognitive network, a set of concepts partially interconnected by various sorts of cognitive links (Craig, 1975). A network model, however, explains the present results only in the rather uninformative sense that an incompletely connected network, viewed in terms of a spacial model, would behave strangely. Some indirect tests of the network hypothesis were tried on the present data. These tests failed and are not reported for reasons of space.

A second explanation is that the experimental messages were noisy; they contained "unintended" information, and so moved the concepts in unintended directions. Here we confront a serious dilemma which no future experiment of this sort can ignore. A realistic, credible message concerning a particular pair of concepts must, it would seem, make references to many third concepts by way of introducing points of comparison or contrast between the experimental concepts. In comparing Fiji and Singapore, for example, we said that both were small, tropical, former British colonies, recently independent, and parliamentary democracies. Perhaps the weakest aspect of this study, in retrospect, was its assumption that the information incorporated in the messages would exert force only along the line directly connecting the pairs of manipulated concepts. In retrospect it would have been just as reasonable, and perhaps more so to assume, for example, that saying Singapore and Fiji are both parliamentary democracies not only would move Singapore and Fiji toward each other but also would move *both* Singapore and Fiji toward the concept "parliamentary democracies." This, then, is the dilemma: on the one hand, we want realistic, credible messages; on the other hand, we can only include a limited number of concepts in the multidimensional scaling analysis. It seems that we must choose either ineffective or invalid manipulations.

Experimental procedures undoubtedly can be developed to avoid the dilemma. One possibility is to pretest the messages in several stages, incorporating, in overlapping parts, all of the concepts referred to in the messages. The main experiment would include several pretested reference concepts and several new concepts. The theory would predict the movement of each reference concept with respect to the other reference concepts on the basis of pretest data, and with respect to the new concepts as a linear function of the predicted movements with respect to the reference concepts. Still another, much simpler, approach is the "Automatic Message Generator" under development by Woelfel and his associates (Woelfel, Holmes, Fink, Cody & Taylor, 1976).

Of more immediate interest, however, is whether some of the unpredicted changes in this study can be accounted for post hoc by the theory in terms of unintended message contents. The answer seems to be yes. The example of Singapore and Fiji is a case in point. Both countries, which were said to be parliamentary democracies having capitalist economies, moved toward the conservative end of the second dimension, which seemed to represent political ideology. Another case concerns Congo. Congo's movement toward the radical end of the second dimension was one of the most prominent changes in the study. This movement, which was not at all predicted, is not at all surprising in view of the assertions, in the message about Congo and Guyana, that Congo has a socialist economy and a one-party government, and is a self-proclaimed communist state. Perhaps we could even explain Brazil's movement toward the African cluster as a consequence of the reference in the message to Brazil as a former colony. Perhaps we could explain Guyana's movement in a general European direction as a result of references to it as a parliamentary democracy or as a member of the British Commonwealth of Nations.

These post hoc explanations must be viewed with appropriate skepticism. They do, however, support the general contention that the noisiness of the experimental messages cannot be ruled out as an alternative explanation which preserves the basic character of the theory of linear motion.

A third and final explanation is that the concepts in this study failed to behave lawfully because they do not compose a *cognitive domain*. Scott (1969) defines cognitive domain as a set of functionally equivalent concepts. It seems possible that cognitive change is systematic only within domains. The concepts in this study may not have composed a single domain for either of two reasons. First, there may have been too many concepts. Studies of human information processing capacity suggest that people can handle about seven chunks of information simultaneously in short term memory (Miller, 1956). Thus, there may be an upper limit to the size of domains. Spaces including more than that number of concepts would not behave lawfully. If the limit is around seven, then this study, with 15 concepts, clearly exceeds the limit. A second reason why the concepts might not have composed a domain is that some of them were possibly too unfamiliar to be meaningful to the subjects. Perhaps there is some critical mass that a concept must attain before it can function as part of a domain. Spaces which include a number of unfamiliar concepts might not be expected to behave lawfully.

The data were examined from several standpoints to test this alternative hypothesis. Particular attention was focused on subsets of about seven concepts that might, for one or another reason, constitute a domain. Predictions of distances involving the seven highest mass concepts, and predictions of the smallest third of the interconcept distances, were examined and found to be no better than predictions for the whole set of distances. Thus, the present study offers no direct support for the contention that concepts can belong to a domain only if they have a certain critical mass or if they are close to each other in cognitive space.

A third subset of distances, however, did conform more closely to the theory than did the data as a whole. These were the distances among the six manipulated concepts: fifteen distances, or if the three directly changed distances are excluded, 12 distances. Table 7 displays the partial correlations (controlling pretest distances) of predicted with observed posttest distances for the 12 indirectly changed distances among the six manipulated concepts. These partials are, on the whole, substantially higher in absolute magnitude than the corresponding partials in Table 6. Few of them are statistically significant, but they have only nine degrees of freedom. Had these partials appeared in Table 6, they would have been touted as strong support for the theory despite some anomalies among them. Two factors seem to favor the theory. The first is the magnitude of the partials. The second is that the best results are achieved with the stable concepts rotation, a rotation which assumes (thus would tend to more adequately reflect) the success of the experiment.

But does this particular subset of the concepts compose a domain in a sense that the whole set of concepts does not? One interpretation is that the six manipulated concepts constitute a domain just in consequence of being manipulated, which entails both being mentioned in connection with each other and being infused with information in the form of experimental messages that might create the needed critical mass. This interpretation is interesting, but it should not be taken too seriously until the finding has been replicated.

Thus the predictions may have failed because they took inadequate account of the concept of cognitive domain. They also may have failed because of other flaws in the experiment, such as inadequate control of message content. They may have failed, finally, because the hypothesis simply is false; cognitive change does not occur along straight lines. In any case this experiment is evidence that there are limits to the applicability of the spacial model of communication effects. This is

TABLE 7
First Order Partial Correlations for Indirectly Changed Distances Among the Six Manipulated Concepts Only

Dimensions Included in Computations	Predictor $A=\hat{s}m_{ij}$ $B=\hat{s}_{ij}$	s'_{ij} Computed From No Stable Concepts Rotation	s'_{ij} Computed From Stable Concepts Rotation	Actually Observed s'_{ij}
1-15	A	.436	.359	.359
	B	.449	.402	.402
1-12	A	.384	.391	.403
	B	.397	.424	.444
1-9	A	.322	.401	.352
	B	.357	.397	.414
1-6	A	.336	.389	.511
	B	.321	* .538	* .523
1-3	A	.335	.020	.165
	B	.362	.040	.163
1-2	A	.333	- .038	- .213
	B	.474	- .104	- .138
1	A	- .490	** .716	.004
	B	*- .553	* .661	- .027

* $p<.05$, one-tailed test, d.f. = 9
** $p<.01$, one-tailed test, d.f. = 9

not to suggest that the spacial model is radically false. On the contrary, the accumulated evidence of many studies strongly suggests that spacial representation of at least some kinds of cognitive *structures* is valid and highly useful, and that spacial representation of cognitive *change* may have some degree of validity under some conditions. The results of the present study are consistent with both of these conclusions. The structural representation of the 15 nations was as meaningful as that of most multidimensional scaling studies. The cognitive motion observed was, however suggestive, considerably less clear than the structure. The question is whether conditions for the applicability of the spacial model of communication effects as motion can be identified.

If every cognitive association in a message produces a measureable force for change, then more careful message construction and more careful pretesting will improve predictions. If cognitive domains must be limited in size, then studies including fewer concepts may achieve better results. If the linear model fails, then a more complex law of motion may succeed. These hypotheses, if one views them as likely bets, are the logical next steps for research on the spacial model.

NOTES

1. This paper is based, in part, on the author's doctoral dissertation (Craig, 1976a), Joseph Woelfel, advisor. Parts of this report were presented at the 1976 ICA convention (Craig, 1976b). Use of the Michigan State University computing facilities was made possible through support, in part, from the National Science Foundation.
2. The authors also discuss "busing," but the movement of the candidate with respect to busing is made ambiguous by the movement of busing itself. Busing and the Democratic candidate are said to have "rotated" with respect to each other, which appears to be a correct description but is theoretically unexplanatory.
3. Each message was about 200 words long and consisted of facts selected from (and attributed to) the *Encyclopedia Britannica*. For example, the message entitled "Facts about Singapore and Fiji" said, in part:

> Fiji and Singapore are remarkably similar countries. Both Singapore and Fiji are small, tropical island countries in the Eastern Hemisphere (Singapore at the tip of the Malay Peninsula and Fiji in the South Pacific North of New Zealand). Both countries have tropical climates—hot, humid and quite uniform in temperature.... Fiji and Singapore are both former British colonies which have attained independence within the past decade. Both countries are relatively stable parliamentary democracies, with multiple political parties and legal systems rooted in the British tradition. Fiji and Singapore are both members of the British Commonwealth of Nations.

4. For a brief, technical explanation of negative roots, see Barnett, Serota, and Taylor (1976, 242, Note 9).
5. I would reiterate the warning offered by Barnett, Serota, and Taylor (1976, 242, Note 10) concerning the interpretation of dimensions. As I pointed out earlier, Woelfel's model de-emphasizes and perhaps discourages such interpretation.
6. Due to an error in the stable concepts rotation routine of the Galileo computer program, previous reports of this study (Craig, 1976a, 1976b) have presented incorrect results for the stable concepts rotation. Tables 5, 6, and 7 contain the corrected results.
7. The eigenvalues given in Tables 3 and 4 are those after translation of the coordinate system to the centroid of the "stable" (unmanipulated) concepts. The eigenvalues mentioned in the text are those prior to translation.

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