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Abstract

It is common in the organizational literature to recognize the importance of both formal and informal organizational social structure. Most investigations of social structure, however, have not been truly structural in nature. This paper explores the applicability of multidimensional scaling and clustering techniques to the representation of social structure as a complex set of relations. Several methodological issues concerning the use of these statistical techniques are reviewed and illustrative data is presented. Finally, the potential relevance of this methodology for organizational design is discussed.

# THE USE OF SCALING AND CLUSTER TECHNIQUES IN INVESTIGATING THE SOCIAL STRUCTURE OF ORGANIZATIONS

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The design of organizations, as with the design of anything, from bridges to poems, must focus on structure. Design is essentially the activity of constructing and changing organizational structure to achieve optimum effectiveness. An emphasis on structure, of course, is not new to organizational thought. Classical theorists were highly concerned with structural characteristics such as the division of labor, line-staff relationships, and span of control. And the popularity of the "systems" metaphor in modern organization theory continues to bring structure to the forefront. Much work remains, however, in developing useful approaches to organizational structure. The present discussion deals with a methodology for investigating one facet of this problem, the interpersonal structure of people in the organization. In describing this methodology, we will attempt (1) to place it within the broader theoretical context of issues concerning organizational structure, (2) to present the results of an empirical application of the methodology, and (3) to examine critically the methodology and its implications for organizational design.

## The Nature of Organizational Structure

Structural analysis proceeds from the recognition that the organization is a system, that is to say, a whole. The next step is to specify the elements of the system, or the parts of the whole. Such elements are the basis of organization. The identification of elements depends on the level of analysis and on, what we will call, perspective. Levels of analysis are usually thought of in terms of a macro-micro continuum. One level of analysis takes entire organizations as its basic unit while another uses individuals in the organization. Perspective usually has implications for the level of analysis adapted but is more general than this. Depending on the investigator's perspective, it is possible to have different structural interpretations of the same thing. For most firms, for example, we can readily speak of their financial structure, the structure of their work tasks, their market structure, or even, between organizations, their industry structure. It is perhaps misleading, therefore, to refer to "<u>the</u> structure of an organization." All organizations possess structure, but a particular characterization of structure always presumes some perspective and level of analysis.

Any structure consists not only of elements but of relations between elements as well. Relations are simply forms of interaction or combination. They may be specified in many different ways, both quantitatively and qualitatively. Logical properties such as transitivity or symmetry may be attributed to them. However elaborated, though, both relations and elements are necessary for any structural description of an organization.

The present discussion approaches organizational structure from the perspective of the people in the organization. The unit of analysis is the person and the relations are the social bonds between people. While this perspective has been the dominant one in the organizational literature, it should be realized that it is not the only one, excluding as it does discussions of technological structure (e.g., Perrow, 1967) and the like. Perhaps the best term for our perspective is "the social structure of the organization." It is easiest to visualize this structure as the place with respect to one another of the people in the organization.

It is common to distinguish between two types of relations between people in an organization. The formal organization, symbolized by the organizational chart, includes authority, work-related communication, and succession relations. These relations are highly formalized and official in nature, usually to the point of written documentation. The informal organization, on the other hand, consists of interpersonal relations such as liking or disliking, casual communication, power, trust, prestige, etc. Both types of relations have stimulated considerable research. It may be useful to review some of this previous work before proceeding.

Research on formal relations

This research has typically sought to develop measures of various aspects of formal structure, attempting to relate these to each other, to environmental factors, or to effectiveness. Work on formal structure originated with Durkheim's (1947) concept of the "division of labor." This notion, of course, refers to the functional division of task activities between people in the organization. The relation is one of overlap or similarity between people in the work they perform. The relative completeness of the division of labor is thus one aspect of formal structure. Current research has continued to emphasize the importance of functional divisions. Blau and Schoenherr (1971) used the number of positions and subunits as a measure of structure. Hage and Aiken's (1967) research on health and welfare organizations employed a measure of professional activity to reflect the extent of each persons occupational specialization. Along somewhat similar lines, Pugh, Hickson, Hinings, and Turner (1968) have used a measure of "functional specialization" based on whether each of a set of activities assumed to be common to all organizations is or is not performed by one or more people full time.

Another structural dimension is given by the obvious hierarchical structure of complex organizations. Traditional theorists have been heavily concerned with the "span of control," or the ratio between supervisors and subordinates. In the same vein, most current research has concentrated on the depth of the hierarchy (Evan, 1963). Pugh et al. (1968) simply counted the number of job positions between the chief executive and employees working on production as a measure of this vertical dimension. Tannenbaum et al. (1974) assigned scores to individuals based on the number of persons both above and below them in the hierarchy. It is common to employ gross classifications of organizations as having either "tall" or "flat" structures and as being centralized or decentralized in terms of decision-making (Porter and Lawler, 1965). The structural dimension being summarized is that of authority between people.

A frequently neglected but clearly significant structural dimension is simply geographical location. The actual physical or functional distances between people comprise a structure within which all interaction must take place. The location of people's offices and their furnishings tend to reflect other dimensions of formal structure but can take on effects of their own (cf. Steel, 1973). It also appears that actual distances may be modified by psychological expectations about the appropriateness of physical relations (Sommer, 1969).

Although functional specialization, hierarchical depth, and physical location have received the most attention, other aspects of formal structure have been postulated. Hage and Aiken (1967) used the notion of "formalization" to refer to the use of explicit rules in the organization. Pugh et al. (1968) defines "standardization" as the application of uniform procedures and "formalization" as the extent to which procedures and rules are written. Such terms represent an attempt to characterize the nature of the communication relation between people.

The approach taken to research on the formal structure of organizations is well reflected in Blau's (1970) statement that "The fact that members of a collectivity are differentiated on the basis of several independent dimensions is the foundation of the collectivity's social structure." As already seen research has concentrated on the dimensions of functional specialization, hierarchical depth, and physical location, though some attempts have been made to include more psychological bases of differentiation (e.g., Lawrence and Lorsch, 1967). One point should be made in concluding our comments on this work. Although the structural dimensions are <u>defined</u> in terms of people (or positions, which are people at a given point in time), the level of analysis is usually that of the organization. Levels of differentiation are compared across organizations. Clearly, however, if one takes the individual as the unit of analysis, people are related to each other along these same dimensions within the organization, and this is the formal structure.

Research on informal relations

Since the human relations school of organizational thought and the Hawthorne studies (Roethlisberger and Dickson, 1939), it has been generally recognized that human interaction is not confined to the bounds of the formal organization. The pattern formed by these additional, more socially determined interpersonal relations is usually called informal organizational structure. Much of psychology and sociology, of course, has been an effort to understand just these interpersonal relations, and organizational theorists have relied heavily on this work. For our purpose, two lines of investigation are most important.

The most common approach has been to rank the members of a group, or simply to categorize them, on some dimension such as status, leadership, control of resources, personality, ability, etc. Rank orders of individuals or groups of individuals on these dimensions may then be related to other variables. Such differentiations along single dimensions are not highly structural in nature though. They do not represent the pattern of relations between individuals but rather, at most, are summary measures based on this structure. Recent research may have begun to recognize this difficulty. In the study of leadership, for example, Hollander and Julian (1968) advocate a "transactional" approach which emphasizes the exchange relations between leaders and followers. Gibb (1969) sees leadership as a concept applied to the "interaction" of two or more people. Unfortunately, such thinking has been generally slow to replace the prevalence of the ranking approach in organizational research.

A much smaller number of studies, mostly in the small groups area, have viewed social structure in terms of interpersonal relations. Cartwright and Zander (1968) list four types of relations which have received the most attention: (1) the relation "A chooses B," to which we will return, (2) the relation "can communicate to" (as in a communication network), (3) the relation "has power over," and (4) the relation of "task interdependence." There have been attempts both to describe the pattern these relations form in ongoing groups and to test the effects of experimentally creating different patterns. Most of the work on the structure of existing groups has employed the first type of relation, sociometric choice.

The relation "A chooses B" has been the subject of considerable interest dating from Moreno's (1934) pioneering group studies in institutional settings. Although measures of sociometric choice have been operationalized in a variety of ways, typically each individual in a group is asked to list persons in the group with whom he would like to engage in some activity and other people with whom he would not like to engage in that activity (Lindzey and Byrne, 1968). Usually, these choices concern various aspects of interpersonal attraction, such as "friendship" or "liking." The data from such choices are presented as a "sociogram," which may be described as follows:

> The sociogram is a diagramic device for summarizing the choices and rejections among members of a group. It employs geometric figures to represent members of the group, and various kinds of lines joining the figures to represent choices and rejections. There is no single convention for the drawing of diagrams but, rather, there are many alternatives available to the investigator (Lindzey and Byrne, 1968, p. 460).

The sociogram thus presents a visual picture of the group. The problem with sociograms is that they are arbitrary. From a given data set, there are an infinite number of possible diagrams, many of which could yield very different impressions of group structure.

Much of sociometric research, or sociometry, has been devoted to developing better, less intuitive, methods of describing group structure. The standard approach has been to view sociometric data in terms of "linkages." As in the sociogram, people are represented as points which either are or are not linked together depending on the existence of a relation. There is no implication, however, about the distance between points as is necessarily the case with the two-dimensional picture given by the sociogram. This approach is amenable to two mathematical tools, matrix theory and graph theory. Cast in matrix terms, the existence of linkages is given by the elements of an N x N matrix. Manipulation of such a matrix may reveal the existence of chains of communication or cliques. Abstract graphs resemble the sociogram but are defined only in terms of points (people) and lines (relations) between points. Graphs have been useful in determining cliques as well as in exploring questions concerning structural balance. The end result of these analyses, it should be noted, is still a structural description based on one relation, that of interpersonal choice.

Strategies for research on organizational social structure

Two distinctly different aspects of organizational structure have been discussed. Formal structure arises from explicit efforts to achieve a rational basis for organization; informal structure stems from implicit, more purely social and psychological needs. Yet both formal and informal structure obviously exist in any organization at the same time. Originating perhaps with Barnard's (1938) work, the thrust of most comparisons of formal and informal structure has it that the formal exerts a dominant influence over the informal. In fact, the informal is usually taken as something of a residual category, as all relations not accounted for by the formal structure. Subordination of the informal side in this manner, however, or greater emphasis on either the formal or informal for that matter, can be misleading. At any given point in time, the formal structure does act to set constraints and bounds on the types of informal relations present. But over time, it is reasonable to assume that the informal structure will also influence formal structure. Thus it is common for the formal structure to be modified to take into account informal developments, as for example with changes in reporting relationships to reflect previous lines of personal communication or power. Moreover, if one focuses on criterion variables, such as measures of job performance, the most tenable hypotheses are clearly ones in which both formal and informal structure have interactive effects.

It is our contention that the best characterization of organizational structure is one which omits any rigid dichotomy between the formal and the informal. Both refer to relations between people. Formal relations are more visible in that they are planned and have both normative legitimacy and a deep historical basis in the concerns of modern organizational life. Informal relations are less accessable, more emergent, and more personal. Neither are really "types" of organizational social structure, but are rather descriptions of various aspects of that structure. The application of the two terms as descriptors is quite clear for some relations, e.g., reporting relations are formal, friendship patterns informal. Other relations are less clear. How does one describe the relation of formalization of communication between people (i.e., the use of written communication, proper forms of address, etc.)? Some researchers, as discussed earlier, have identified such formalization with formal structure since it is often prescribed by the organization. In many cases, though, formalization has more to do with the dispositions of the people involved than with any prescriptions, and may be more readily described as informal in nature. All of which means that, although it is useful to employ the terms "formal" and "informal" to refer to different structural relations, this usage does not imply the existence of separate structures.

One further clarification must be added before continuing. Formal structure has two different points of reference. One usage is associated with the written or at least verbal documentation which is imposed on the organization by the managerial function. This formal structure, call it the <u>codified formal structure</u>, takes on an existence of its own separate from the perceptions of the individuals involved. This formal structure may be more or less extensive but almost always has a pervasive influence. It can serve as a goal and a guide for members of the organization and can be changed only through deliberation. Quite apart from this legalistic specification of formal structure, which will always be more restricted in scope, one can examine the social structure which actually exists. In some cases, there will probably be a high degree of congruence between the codified formal structure and those aspects of the actual social structure which may best be <u>described</u> as formal in nature. The codified formal structure, in other cases, may be a misrepresentation of actual social structure, either due to some factor such as timing (e.g., the recency of formal documentation) or to deliberate deviations motivated by other objectives within the organization.

Our conceptualization of organizational social structure has distinguished between the codified formal structure and the actual social structure, aspects of which may be described as either formal or informal. The next question which naturally arises concerns the measurement of social structure. Several possible research strategies may be adopted. One important consideration concerns what is taken as the object of the measurement process. If interest is in the codified formal structure, research should be directed at relevant documents and authoritative statements. Results should not, however, automatically be assumed to apply to the actual social structure, as frequently occurs in the comparative literature. Moreover, the locus of the actual social structure can be taken differently. Social structure exists both as the shared perceptions individuals have of people in their organization and as patterns of interaction. In terms of research strategy, this implies two possible sources of data, self-reports of judgments which reflect relations between people or measures of specific behaviors which indicate relations. For instance, reports of who talks to whom yield data about the perception of communication patterns while behavioral measures of actual communication acts such as phone calls are objective indicators of communication patterns. Sometimes self-report measures will match those based on behavior, sometimes they will not. Given our present level of knowledge, perceptual or judgmental data is probably easier to interpret. The problem with behavioral measures is that they are difficult to operationalize.

Of all the behaviors we might observe, how do we know which ones should be taken as an indicator of a given relation? There are many actions which might indicate the relation of power. Without better developed theories, it is difficult to know which to measure within the context of a particular organization. Research employing perceptual data may be of more help in developing theory, which would in turn allow more meaningful selection of behavioral measures.

There is also a second, more general consideration in research strategy. Two approaches to the analysis of behavioral science data can be distinguished (Shepard, 1969). The more traditional approach is oriented toward the detection and statistical evaluation of patterns of a given hypothesized form. The other is oriented, in Shepard's terms, to the problem of discovery of new patterns. The discovery problem is really one of pattern recognition. The aim is to uncover structure in the data. Shepard (1969) even goes so far as to cast the problem in human-engineering terms. He suggests that data analyses of this sort should be matched to the human abilities needed to comprehend them, arguing that a visual mode of representation of the results would be most effective. Since we really have no firm theories of organizational structure to test, Weber's concept of bureaucracy aside, this logic seems to us imminently applicable. What is needed is a methodology which allows us to detect and represent in a useable form the information about social structure inherent in a given data set.

The class of statistical techniques of which such a methodology might be composed are, of course, cluster analysis, factor analysis, and scaling. We should perhaps recognize that factor analysis has already seen considerable use in this area. Much of the research referred to earlier, notably that patterned after the work of the Aston group, employed factor analyses of a set of dimensional ratings obtained for many organizations. But the question addressed by research of this type is really the evaluation of the independence of the a priori dimensions for which ratings have been obtained rather than the discovery of structure. Recent developments in multidimensional scaling (MDS), the technique emphasized in the methodology to be presented here, offer a greater possibility of truly revealing underlying social structure.

## An MDS Methodology For Organizational Social Structure

Our methodology for exploring organizational social structure derives from a research strategy of attempting to discover structural characteristics from perceptual data. The approach is similar in spirit to that taken by Jones and Young (1972). They conceive of social structure in the following terms:

> Our concept of interpersonal perception implies that each individual in a social field has an internal representation of the other members in the field, with the individual positioned somewhere in the representation. This is his own personal "social environment." We will use the term "social structure" to refer to the pattern of this environment: the systematic relationships among the persons composing the structure (1972, p. 108).

Although this "definition of interpersonal perception" is conceptually appealing, especially in its emphasis on social structure, one must be very careful about references to "internal" representation. What we are trying to do is represent how individuals represent those entities in their social world which are certain people with whom they interact. There must be some correspondence between the two representations, the internal and the one achieved by our methodology, but the two need not be of the same form. Specifically no claims are made about whether the internal representation is digital or analogue (cf. Attneave, 1974) or about the level of awareness and other phenomenal aspects associated with it. As previously discussed, an analogue, or map-like, representation is desirable for our methodology because it is better suited to our ability to detect patterns. The question of internal representation must remain largely a matter for further research.

Jones and Young (1971, 1972) employed Carroll and Chang's (1970) individual differences multidimensional scaling (INDSCAL) model in measuring the social structure of an academic department. While the methodology described here does not employ the INDSCAL model, it is quite similar to their overall approach. The data to be presented are also from an academic department, thereby affording a useful comparison with the results of Jones and Young. In addition, our work has been influenced by the research of Fillenbaum and Rapoport (1971) on semantic structure. They used nonmetric multidimensional scaling and cluster analyses of subjects' judgments about words to construct subjective representations of semantic structure. Aside from its methodological sophistication, this research has also been of benefit in pointing out the value of an independent source of reference for the structural representation generated. In their research, subjective structure was compared to that developed by formal linguistic theories. Though the analogy is not complete, what this suggests to us is to compare our representation of social structure with the codified formal structure of the organization, which is after all rationalistic in nature. Such comparisons should make the results of our research more meaningful both from a theoretical and a design point of view.

Background and assumptions

In our earlier discussion of relevant research we noted two principal ways in which social structure has been measured. One was the linkage methods typified by much of the sociometric literature. People either are or are not joined by a relation, as when the points in an abstract graph are connected by a line. The most common method, though, was the unidimensional scale. Individuals are placed along a spatial continuum according to their possession of some attribute such as authority. If this scale is at an interval, or metric, level of measurement, the distance between any pair of people may be considered the relation between them. It is thus possible to say whether persons A and B are more closely related than B and C. When the scale is ordinal, or nonmetric, such comparisons are not possible. In this case we do not know the relation between A and B, and the measurement conveys limited structural information. The concept of distance is thus critical to this type of structural representation.

Multidimensional scaling differs from simple unidimensional scales in that people may be located within a two-dimensional plane or even a space of higher dimensionality. Clearly this simultaneous representation in more than one dimension offers a better chance of revealing patterns of social structure. At the heart of this representation is the concept of a metric space (Green and Carmone, 1970). A metric space is one for which there exists a well-defined distance function. Euclidean distances are most common and are given by

$$d_{ij} = \left[ \sum_{k=1}^{r} (x_{ik} - x_{jk})^2 \right]^{\frac{1}{2}}$$

where the distance d between any two points i and j is equal to the square root of the sum of the squared differences in the coordinates on each of the k dimensions, k = 1, 2, ...r. Actually this function is a special case of a more general function, the Minkowski r-metric, so that there are several possible functions, including the so-called city block metric in which distance is the sum of the absolute differences in the coordinates on each dimension. Shepard (1969), however, suggests that the Euclidean metric is quite robust. Whatever the metric, structural relations are represented as spatial distances.

Although there are differences in the specific computational algorithms employed, all MDS techniques proceed in a similar fashion in achieving a representation in a metric space. The object is to find a set of coordinate points for which the ratio-scaled interpoint distances best fit the rank order of distances in the input data. (In nonmetric MDS, the input data are assumed to be scaled ordinally, so that only the rank order of the interpoint input distances are used.) These algorithms start with a configuration of points, either arbitrary or supplied by another technique such as factor analysis, and iteratively attempt to find an arrangement as close to this configuration as possible subject to the constraint that the interpoint distances preserve the ranks of the original data. It turns out that any rank order may be represented exactly if there is only one more point than the number of dimensions. A further goal therefore is to employ as low a dimensionality as possible. An important problem is to assess departures from perfect fit. Several measures of "stress" have been proposed which measure goodness of fit, the extent to which the relationship between the final interpoint distances and the input ranks approach monotonicity. These measures of stress tend to yield similar results (Shepard, 1969). For a fuller exposition of multidimensional scaling, Green and Carmone (1970) provide an introduction and the two volumes by Shepard, Romney, and Nerlove (1972) a convenient source of theory and applications.

MDS procedures have been designed for the analysis of a two-way matrix of numerical or ordinal data. In terms of Coomb's (1964) classification of types of data, they may be applied either to relations of dominance or consonance in which the relation is on pairs of points and in which the points come from either the same or different sets. The type utilized in the present study is known as proximity data and involves the comparison of pairs of people belonging to the same set (members of an organization). Proximity data is given by almost any measure of similarity, association, or substitutability. It should be noted again that the level of measurement for nonmetric MDS is that of the ordered metric scale, an ordinal ranking of interpoint distances. The final representation is fully metric.

The specific form of the data is an intact, unconditional symmetric matrix of proximities between all pairs of people. A valuable distinction is between direct and derived measures of proximity. A direct measure is "one which emerges from each pair of objects under study as a primitive datum about that pair (Shepard, 1969, p. 10)." Derived measures are calculated from a larger set of data. The product moment correlation of each pair of person's answers to the items on a questionnaire, for example, would yield a derived proximity matrix. We employ a direct measure of proximity here because, as previously discussed, this has the advantage of not biasing individuals with response categories specified by the investigators. Respondents were asked to judge the similarity between pairs of people. As noted by Fillenbaum and Rapoport (1971), however, when such measures are averaged over people for aggregate analysis, they become a type of derived proximity measure.

Treatment of a particular matrix as proximity data does not depend solely on the properties of the data itself (Shepard, 1969). There is also the question of the relation between the model and the data. In the case of judged similarities, a spatial model is intuitively appealing in that the concept of physical distance matches the psychological notion of judged similarity. But the same set of data can be viewed in alternative ways and analyzed by other methods to reveal different aspects of structure. Similarly, there is by no means any guarantee that a model which assumes a continuous space of well-defined dimensionality is an appropriate representation for a set of ordinal data. It may be, as Miller (1969) has argued for semantic structure, that taxonomic or typal structures based on the relation of class inclusion are more suitable. Or it may be that both dimensional and taxonomic properties are required for structural description.

It is advisable then to supplement MDS results with dimension free analyses (Fillenbaum and Rapoport, 1971; Green and Rao, 1972). Cluster analyses are typically used for this purpose, with the most common method being Johnson's (1967) hierarchical clustering schemes (HCS). When Johnson's procedure is applied to a symmetric proximity matrix, it generates clusters hierarchically such that there is a range from a weak clustering in which all objects (people in our case) are represented as separate clusters to a strong cluster in which all people are grouped in the same cluster. At each stage in between, the recursive algorithm forms a new cluster by combining either two people, a person and a previously formed cluster, or two clusters. A person cannot be removed from a cluster once placed in it. The pair combined at each stage is the one with the smallest entry in the distance matrix. After they are merged a new distance matrix is computed. The distance between the new cluster and another person or cluster may be taken as either the smaller distance from the original two pairs (the connectedness method) or the larger distance (the diameter method). In practice the diameter method usually yields better results (Fillenbaum and Rapoport, 1971; Green and Rao, 1972), and is employed in our methodology. The hierarchical nature of the HCS representation would seem quite appropriate for many aspects of organizational social structure.

The methodology

Two types of raw data are collected for our methodology. Subjects are first asked to rank order a deck of cards containing all possible pairs of people in the social structure. Each card contains one pair of names. The cards are generated by a computer program (Calder and Rowland, in press) which arranges them according to a scheme developed by Ross (1934) so that the initial order minimizes systematic repetitions which might have suggestions effects and maximizes the space between pairs having people in common. The cards are standard computer cards which have been interpreted so that the names are printed at the top.

Subjects are instructed to rank order the pairs of names in terms of their "similarity." Without providing the subjects any cues on which to base their judgments, similarity is further defined as follows:

You will be given a card for each possible pair of people who appear on the list and asked to make a judgment about each pair. Based on the way you normally view the (name of organization or unit, in terms of your everyday activities, try to judge how similar the two people are to each other.

By similarity we mean the extent to which the two people seem to "go together" as far as your actions are concerned. This similarity or closeness judgment may be based on any factors which seem important to you. However, try to maintain the point of view of your everyday life in the (name of the organization or unit).

Subjects are then given written instructions for sorting the cards:

1. First sort the paired-name deck into six piles of cards, ranging from most similar to least similar. The piles do not need to contain an equal number of cards.

2. Then sort the cards within each pile from most similar to least similar. Cards may be moved from one pile to another.

3. Next merge the piles so that the pile with the most similar paired-names is on top, the pile with the next most similar paired-names is next, and so forth until the pile with the least similar paired-names is at the bottom or back of the deck. This procedure should give you a general ranking of all paired-names from most similar to least similar.

4. Finally, go through the merged deck again to check your ranking of paired-names and make any changes you wish to make.

5. When you have completed sorting the deck in this manner, please return the sorted deck.

Work slowly and carefully; this is a difficult task; take your time. If you have any questions about this task, please ask them now.

When the subject has completed the sorting task, he is then given a questionnaire inquiring about various characteristics of the people involved. Each question requires him to rate each person on a scale of 0 to 7. These rated attributes or properties are helpful in interpreting the MDS results. Their limitation is that the questions are based on the a priori hypotheses of the researchers.

Once the stimulus decks have been sorted, they are resubmitted to the same program which generated them. Each card contains a punched identification code which has not been interpreted and, consequently, is not noticed by the subjects. The output of this program is a lower triangular matrix of stimulus pair ranks. The elements in the matrix are simply the rank in the sorted deck of a particular pair of people. Since each pair is ranked only once, the within-pair ordering being balanced over pairs, all entries may be placed below the diagonal of the matrix. The higher the rank, the less the similarity between the persons in that pair. The raw data thus take the form of a proximity matrix, one for each subject.

The next step, as shown in the flow diagram of our methodology presented in Figure 1, is to aggregate the raw data matricies. There

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Insert Figure 1 about here

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will, of course, be individual differences in the rankings provided by different subjects. Now it is possible to treat each subject as an independent replication and differences as error variance. The matricies could then be averaged over subjects to produce grouped data. The problem with this is that individual differences may not reflect only errors but also genuine differences in perception. Grouped data in this case may yield MDS solutions which are not representative. At the other extreme, the data can be treated in a disaggregate manner with MDS analyses performed for each subject. This has the disadvantage of being difficult to interpret for large numbers of subjects and being very expensive. What is needed is a middle approach which provides for aggregation but somehow allows for individual differences. Several proposals of this type have been made. The procedure adopted here is described below. It will be compared to other approaches in the next section.

The present methodology attempts to take a very straightforward approach to aggregation. The question of individual differences is posed as the first step in the analysis of the data (see Figure 1): Are there important differences in the rank orders in which different subjects have sorted the paired-comparison stimuli? And, if so, can subjects who have similar rank orders be identified? To answer these questions, the lower triangular matrix for each subject is rearranged as a column matrix, creating a list composed of the ranks of the stimulus pairs, one list for each subject. It is then possible to compare a subject's ordering with any other subject's on the basis of some index of matching. One such index, proposed by Johnson (1968), compares subjects on the basis of the size of the intersection of their sortings. The size of the intersection is given by the number of paired stimuli on which the rankings agree. In the present context, however, Johnson's index has the disadvantage of not being sensitive to small discrepancies in the rankings. The intersection would be empty if all of one subject's ranks were only once removed from another's. A less restrictive index is required, and for this reason the rank order correlation between each pair of subject's rankings was selected. These rank order correlations can be arranged to form a lower triangular matrix in which the rows and columns are subjects.

Once this association matrix has been computed, the question of which subjects should be grouped together can be examined. A nonmetric procedure which identifies the largest possible, mutually exclusive groups is called for. Since the elements in the correlation matrix can be treated as distances, Johnson's hierarchical clustering can be used for this purpose. The rank order matricies for subjects who form clusters are aggregated. Those for subjects not included in a cluster must be analyzed individually.

Aggregation of the individual matricies is accomplished by computing the square root of the mean of the squared individual entries for each element of the matricies. The root mean square (RMS) method of averaging, under some assumptions, appears to distort the grouped configuration less than mean data (Horan, 1969). At this point one is left with a set of either grouped RMS or individual similarity matricies. These matricies may be submitted directly to the multidimensional scaling and clustering procedures. The MDS computer program employed was Young's (1972) POLYCON program.

Since the reference axes of an obtained MDS configuration are arbitrary, it is necessary to rotate them to find a more meaningful position. This reorientation is usually designed to produce "simple structure." In our analyses a varimax rotation is performed to produce coordinates which are either large or close to zero. This ensures that the obtained axes maximally discriminate among the points.

Apart from the orientation of the reference axes, a more basic problem concerns the number of these dimensions. There is no inherent dimensionality in a data matrix. A best-fitting configuration can be obtained in many dimensions. Goodness of fit does increase with the number of dimensions, but this is not the only consideration. Shepard (1972) lists three criteria in addition to goodness of fit. The representation should be statistically reliable. That is, one should be able to replicate the data. It should also be interpretable. If the configuration makes sense, it would seem more likely that the dimensions are real. Finally, Shepard (1969, 1972) puts great importance on how visualizable the representation is. The last three criteria all argue for low dimensionality. With a higher number of dimensions, the representation will be more susceptible to error and therefore less reliable and interpretable. Moreover, a configuration cannot be visualized in over three dimensions. In view of the obvious importance of the latter criteria for design, a space of either two or three dimensions seems most appropriate for the present work.

Once the number of dimensions has been selected and these axes rotated, other techniques may aid in further interpretation. The results of the hierarchical clustering, for one, can provide valuable information about local and typal structure when compared with the dimensional representation. Second, the relation between the configuration and external data can be assessed. The external data in this case, as noted before, are questions which reflect the researchers hypotheses about important aspects of the social structure being investigated. Subjects are asked to rate each person including themselves on each of these properties. The average rating of each stimulus person becomes the values of an external property variable. New axes for the configuration may then be obtained such that the projection of points in the configuration on a new axis has maximum correlation with the values of an external property variable. These new axes are best thought of as a vector which uniquely corresponds to the outside variable. Property vectors need not be orthogonal and there may be more or fewer than the number of dimensions.

A multiple regression procedure may be used to fit each property vector to the configuration. The external property values are the criterion variable and the projections on the reference axes are the predictors. The multiple correlation coefficient reveals the extent to which the property variable is linearly related to the dimensions of the configuration, and is invariant with respect to the rotation of the axes. The normalized regression weights are the direction cosines of the fitted property vector. The higher the weight, the smaller the angle between the fitted vector and an axis.

It must be remembered that this multiple regression analysis is only useful for the specific interpretation of a given representation. We do not wish to label dimensions in the same sense as this is done in factor analysis. A similar orientation of a property vector and a reference axis guides the interpretation of that axis but does not explain an underlying dimension per se.

The axis is not uniquely oriented and might correspond to another vector if the reference axes were rotated. Moreover, not all potentially important properties have been measured, and the mere association of a property and an axis certainly does not provide a causal explanation. Thus, the spatial representations presented to illustrate the results of this methodology are interpreted only in terms of the reference axes shown, not in terms of the latent nature of the dimensions.

Illustrative data

As a first application of this methodology, we chose the Department of Business Administration at the University of Illinois. It was felt that our experience in this organization (the first two authors were faculty members and the last a graduate student) would facilitate interpretation of the results, especially in this first application. Although we have subsequently employed the methodology in a number of field settings, the University data still provides a convenient illustration. A more detailed presentation of the results of this study is given in Calder, Rowland, Leblebici, and Marlow (in preparation). As with most academic departments, this organization has a "flat" formal structure. Figure 2 provides a chart of the codified formal structure.

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Insert Figure 2 about here

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The principal aspects relate to academic specialization and rank. The letters shown on this chart stand for the individuals serving as stimuli. The same set of people participated as subjects. Approximately ten percent of the people in the department were randomly excluded from the study in order to reduce the number of stimulus comparisons.

Hierarchical clustering of the rank order correlation matrix giving the assocation between each pair of subjects' rankings was performed to determine which subjects ould be grouped together. The two largest clusters found were the following:

Group 1 contained individuals B, C, E, H, J, K, L. M, N, O, Q, R, and S.

Group 2 contained individuals F and G.

(Individuals A, D, I, P, and T were not included in the clusters selected.)

The RMS aggregate similarity matricies for the Total Group, Group 1, and Group 2 as well as the five nonaggregated matricies for the individuals not entering clusters served as the basis for further analyses. For clarity of presentation, the results for only the aggregate data will be discussed.

Consideration of the stress values of the MDS solutions in two, three, four, and five dimensions, as well as the other criteria described above, led to a decision to employ a three dimensional representation of the University data. Figure 3 displays this representation for the data aggregated over all of the subjects (Total Group). It is included for purposes of comparison. Figures 4 and 5 contain the representations for Group 1 and Group 2 respectively. (These graphs were produced by a computer procedure due to R. Ray of the University of Illinois' Center for Advanced Computation.)

Insert Figures 3, 4, and 5 about here

Inspection of the three configurations reveals that they are clearly different. The Total Group is similar to Group 1, not surprisingly, since it is based to a large extent on common data. There are, however, differences, indicating the value of clustering subjects. The two subjects comprising Group II seem to be much less differentiated in their perceptions than those in Group 1. Indeed, when the same scale is used for both graphs, the representation shown in Figure 5 seems to collapse around the origin of the space. Since a uniform stretching of this scale is permissible, it is possible to redraw this representation to reveal the distances between stimuli (see Figure 6).

Insert Figure 6 about here

Focusing first on Group 1, compare the structure shown in Figure 4 with the codified formal structure in Figure 2. Notice that the four areas of academic specialization seem to be ordered along the second dimension. The external property variables listed in Table 1 provide

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Insert Table 1 about here

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an additional source of interpretation. The multiple correlation between each property variable and projections on the three dimensions indicates the maximum correlation between a fitted property vector and values of the property variable. Table 1 reveals that only two of these correlations are nonsignificant, familiarity with a stimulus person and the orthodoxy of his life style. The highest correlation is with a question regarding a person's interest in behavioral research, ranging from none to extremely behavioral. Other high correlations were obtained for a conservative-liberal continuum, career potential, interest in quantitative research, etc.

These correlations demonstrate that the obtained space does predict certain unidimensional judgments made by the subjects. Along with the direction cosines given in Table 1, they also help with the interpretation of the reference axes shown in Figure 4. The first dimension is very similar in orientation to the fitted property of power and, to a lesser extent, professional status and activity. Interpretation of the second dimension is less clear. Conservative vs. liberal views, amount of social contact, and interest in research all appear relevant. These properties are consistent with our earlier observation that the four functional units of the codified formal structure are ordered along this axis. Organizational behavior faculty are perceived as more research oriented than marketing faculty, and marketing faculty more so than management science faculty. The same ordering would seem to apply to social contact and conservative vs. liberal views, with management science faculty being perceived as more conservative and having less social contact. The third dimension is most similar in orientation to perceived interest in teaching and, to a lesser extent, with quantitative focus, faculty at the top of Figure 4 being more interested in teaching and less quantitative.

The results of a hierarchical clustering analysis for Group 1 is presented in Figure 7. The people connected by X's at each level form

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Insert Figure 7 about here

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clusters. Significant clusters ($p < .05$) have a line drawn through the X's. One significant cluster contains [G, I, L, M] and is part of the larger cluster [D, G, I, L, M]. This cluster includes all but one of the management science group. Interestingly enough, members of this group would probably dispute the inclusion of K in their group. Another significant cluster contains [A, H, J, O, R, T] which is part of the larger cluster [E, P, Q, A, H, J, O, R, T], and this is part of [F, N, S, E, P, Q, A, H, J, O, R, T]. Although the meaning of these hierarchical levels is not readily apparent, the fact that they can easily be embedded in the dimensional space is encouraging. The largest cluster contains all but one of the organizational behavior and marketing faculty. This analysis reinforces our interpretation of the second dimension as reflecting perceived differences in the subunits of the organization.

In completing our examination of Group 1, some attention should be given to property vectors which have high multiple correlations but are not aligned with a reference axis. Career potential is similar in orientation to the first and second axes, with individual O being high on this property. Likeability is more oriented toward the second and third axes, with individual J being high on this property. The best fitting property vector, perceived emphasis on behavioral research, runs diagonally through the configuration with organizational behavior and marketing faculty being more behavioral than management science. There is a diagonal orientation for applied interests too, with individual K being high on this property.

The same multiple regression analyses were performed for Group 2 (see Figure 6). For the external property variables, only two significant multiple correlations were obtained. These were for quantiative focus and interest in behavioral research. The resulting property vectors were not aligned closely with any of the reference axes. In addition, the hierarchical clustering analysis gave a similar pattern of results. Only one significant cluster was obtained and this included sixteen individuals. Only D, G, L, and T were excluded from the cluster, these individuals having extreme values in the MDS configuration too. This supports our earlier conclusion that the two individuals in Group 2 (F and G) are relatively less differentiated in their perceptions than those in Group 1.

The representations of organizational social structure developed in these analyses lead directly to substantive implications. From a theoretical point of view, the mirrowing of the functional areas of specialization in the representation for Group 1 is intriguing. The codified formal structure is clearly reflected in individuals' perceptions of each other. Of relevance, too, are teaching interest, quantitative focus, and other more formal characteristics relating to the work performed. The importance of power and status is also apparent as well as other informal characteristics such as social contact. These results bear out our argument that both formal and informal factors are integrated into the social structure. Moreover, the structure obtained is similar to the one generated for the L. L. Thurstone Psychometric Laboratory by Jones and Young (1971, 1972). Since the reference axes yielded by their method were unique, they sought to label the dimensions obtained, calling them status, professional interests, and political persuasion. These characteristics correspond to several of the properties found to be important in the present study.

From a design point of view, our results suggest that the codified formal structure may have some unintended effects in this organization. There seems to be something of a gap between the organizational behavior and marketing faculty and the management science faulty. There are two other immediate observations. One is that several individuals are perceived by Group 1 as different from most people in their unit or even in the organization. The second is that the individuals in Group 2 are clearly somewhat out of touch with the majority's view of the department. All three of these could have implications for the performance of the organization. Our purpose here is not to pursue such an analysis, but hopefully to suggest the richness of the kind of information yielded by the methodology.

## Some Methodological Issues

In completing our overview of this MDS methodology, we should return to a few issues for more careful attention. It should be emphasized that there are many far from settled questions, and these need to be explored by further research.

The task for subjects

One vital issue concerns the task posed to subjects for the collection of data. This problem must be addressed in terms of the meaningfulness of the task for subjects and its efficiency as a data collection device. As previously discussed, the main advantage of simply asking subjects to make overall similarity judgments is that subjects are not biased toward any specific criteria. Instructions to judge "similarity," however, inevitably entail some ambiguity. Subjects typically request clarification, and may be frustrated by evasive answers. Even the concept of similarity is not as clear as it might first appear. It is possible, for instance, for two individuals to be so different that they are similar. They may be similar in that both are deviates, but perhaps different kinds of deviates. How does a subject judge their similarity? We can argue, of course, that he makes his judgment according to how he perceived people, and that this is precisely what we wish. But such ambiguity is still a potential source of error variance.

There are other ways of collecting similarity data besides requiring judgments of similarity. There are various construction methods in which the subject is asked to do something, such as draw a graph (Fillenbaum and Rapoport, 1971), from which rankings of the proximity of people can be obtained. Plus there is always the possibility of deriving similarity measures from other data. While similarity judgments are appealing in their lack of bias, it would be useful to compare the results of different methods.

In terms of efficiency, the method of paired-comparisons has severe limitations, requiring each subject to make some N(N-1)/2 judgments. Subjects in our faculty study made 190 comparisons, which is probably approaching the upper limit set by boredom or fatigue. Other techniques, using derived measures, offer the possibility of sidestepping this limitation.

Selection of stimulus people

Care is required in selecting the domain of people under study. There are practical limitations on the number of pairs of people for which similarity judgments can be obtained, and limits on the number of stimuli which can be scaled by existing procedures. The stimulus domain is constrained by the boundaries of the organization, but this often includes more people than can be handled as stimuli. Our solution to this in the faculty study was simply to eliminate a few individuals on a random basis. The assumption being that the obtained representations would be so overdetermined as not to be highly sensitive to these omissions. The appropriateness of this assumption depends heavily on the organization being studied and the purpose of the study. Some organizations may be so complex that even leaving out one or two people would yield a different picture of social structure.

Aside from sheer size, the most important factor in selecting a domain of people is whether they form a coherent set. By coherent set we mean there should be some reason for believing that a structural pattern exists in the relationships between the people. The reason underlying our selection of domains has been the codified formal structure. Since our methodology is going to yield a structural representation, no matter what, we must have a basis for believing that one exists and an idea of what it involves.

Where the stimulus domain exceeds, say, twenty-five people, the present methodology is just not applicable. This is not as restrictive as it may sound. The methodology is not limited to small groups confined to one part of the organization. For instance, in investigating a very large organization, we used department heads and assistant department heads as stimuli. These individuals formed a coherent set in terms of the codified formal structure, and yet spanned the entire organization.

Individual differences

Two general approaches can be taken to individual differences in the application of MDS procedures. Subjects may be partitioned into groups for separate analyses, or an attempt may be made to incorporate the individual differences directly into the scaling model. The INDSCAL model developed by Carroll and Chang (1970), and used by Jones and Young (1971, 1972) in the study discussed earlier, is an example of the latter approach. This model assumes that a common stimulus space of *r* dimensions underlies the judgments of subjects. Individual differences are accounted for by differential weighting of the common dimensions by subjects. The problem with this method is that it may require a solution in too many dimensions in order to be sure of capturing important individual differences. Unless there is some reason to suspect a high degree of commonality in the dimensions employed, the approach of partitioning subjects before scaling seems to us more appropriate.

Perhaps the most widely used technique for partitioning subjects is the "points of view" analysis developed by Tucker and Messick (1963). A matrix of stimulus pairs and subjects serves as input to this procedure. Factor analysis of this matrix yields groups of people who are similar in their judgment of the stimulus pairs, who, in other words, have similar points of view. The method of dealing with individual differences employed in our studies is obviously similar. Instead of factor analyzing the matrix of rank order correlations, however, a cluster analysis was performed. The cluster analysis seems preferable in view of certain criticisms of the points of view analysis (Ross, 1966) and because it is, unlike points of view analysis, a nonmetric procedure.

The fact remains that our procedure of clustering the rank order correlation matrix is not very powerful. Techniques are needed for determining which dimensions subjects have in common and which they do not in terms of a group representation.

Dimensions and properties

As previously discussed, the number of dimensions chosen for a representation of social structure has more to do with the techniques employed and our ability to comprehend the results than with any intrinsic dimensionality. Our methodology does not provide evidence about all of the many social relations possible in a setting. The objective is to discover only the most important relations. The advance over previous research lies in the ability to detect structural patterns other than ranking or grouping people along a single continuum.

No attempt as such has been made to label the dimensions obtained, since they are not unique. Perhaps it is best to think of dimensionality as the degree to which the data have been compressed. The search for structure takes place within a given set of dimensions. Through the use of external property variables, visual inspection, and clustering, one attempts to find patterns. The reference axes are of particular interest since they are oriented so as to provide maximum interpretability, in the particular sense of a varimax rotation. But the direction of other vectors in the space is important too.

It is possible, of course, to pass any number of vectors through the space. A crucial problem which must be addressed by further work has to do with the causality of these outside variables. The intercorrelation between the variables is such that a general direction in the space may be associated with many variables. This association will be spurious for some though. In Figure 4, for instance, the axis denoting the second dimension is similar in orientation to conservative vs. liberal views, social contact, and interest in research. But one suspects that what is being represented is simply the functional divisions of specialization in the organization. This specialization in turn happens to be correlated with many other things, from aspects of that specialization (e.g., interest in research) to ecological covariates (e.g., social contact). Likewise, the second dimension axis is associated with interest in teaching and a quantitative focus. The latter is probably due to the perception that quantitative faculty are poorer teachers. If true, the structural pattern should be interpreted in terms of teaching interest, not quantitative focus.

A simple demonstration of predictive ability between a multidimensional space and a unidimensional property judgment is not enough. Attention must be given to the underlying causality for correct interpretation. The application of causal models might be a fruitful approach.

MDS representations as structural descriptions

At the outset of this paper, we pointed out that any structure consists not only of elements but relations between elements. We feel that one of the chief advantages of an MDS representation lies in its treatment of relations. At least for interpersonal perception, it is probably best to think in terms of a single relation between people. There are not separate relations of task specialization, liking, status, and so on. People are perceived to be more or less related, this relation being affected by many factors such as liking, etc.

Although this treatment of relations is conceptually appealing, we must exercise some caution with the present methodology. Since the dimensions themselves are not interpreted, the evaluation of the importance of various factors for a relation becomes more difficult.

## Conclusions

The methodology discussed in this paper has two main strengths as a tool for organizational design. One is that it attempts to detect structure without the potentially biasing effects of a priori hypotheses. Patterns are revealed by subjects' own judgments. The other is that it provides a visual source of comparison (if three or fewer dimensions are used). A representation of a given social structure can thus serve as a point of reference. It can be compared to the codified formal structure or with representations of other organizations. Repeated applications can be used to monitor the effects of change programs over time. Finally, a representation might even be used as an agent of change by showing it to the individuals in the organization.

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Table 1

Results of the Multiple Regression Analysis for Group 1

| Property Variable | Multiple Correlation | F | Direction Cosines Axis I | Axis II | Axis III |
|---|---|---|---|---|---|
| 1. Familiarity | .39 | < 1 | -.31 | -.35 | .88 |
| 2. Professional status | .81 | 10.34** | -.89 | .07 | -.43 |
| 3. Power | .76 | 7.19** | -.96 | .23 | -.12 |
| 4. Active | .62 | 3.40* | -.93 | .04 | .36 |
| 5. Interest in teaching | .76 | 7.12** | .22 | .25 | .94 |
| 6. Interest in research | .89 | 20.87** | -.28 | -.85 | -.45 |
| 7. Quantitative | .86 | 14.79** | .41 | -.34 | -.84 |
| 8. Behaviorally oriented | .95 | 52.94** | -.53 | -.65 | .54 |
| 9. Applied | .86 | 15.85** | -.42 | .56 | .70 |
| 10. Social contact | .69 | 4.97* | -.37 | -.92 | -.12 |
| 11. Orthodox life style | .57 | 2.62 | -.25 | .55 | .79 |
| 12. Conservative-liberal | .91 | 25.06** | -.08 | -.98 | -.20 |
| 13. Likeable | .68 | 4.72* | -.15 | -.64 | .75 |
| 14. Career potential | .90 | 21.84** | -.77 | -.60 | -.23 |

*p < .05, df = 3/16.

**p < .01, df = 3/16.

## Figure Captions

Figure 1. A flow diagram of the methodology.

Figure 2. The codified formal structure (each letter represents a faculty member).

Figure 3. MDS representation for the Total Group.

Figure 4. MDS representation for Group 1.

Figure 5. MDS representation for Group 2.

Figure 6. MDS representation for Group 2 with expanded scale.

Figure 7. Cluster analysis for Group 1 (HCS, diameter method).

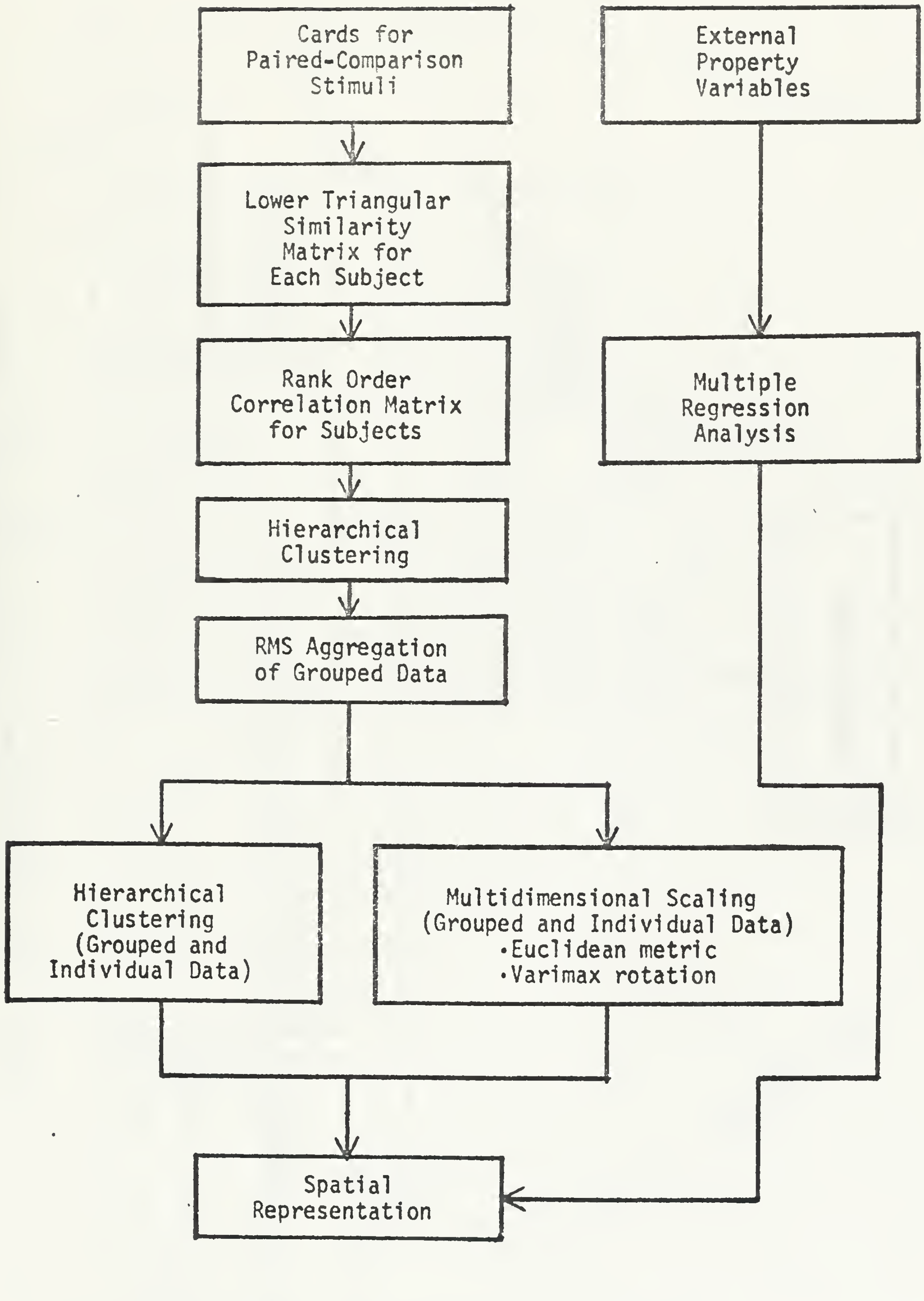


Figure 1. Flow diagram of methodology.

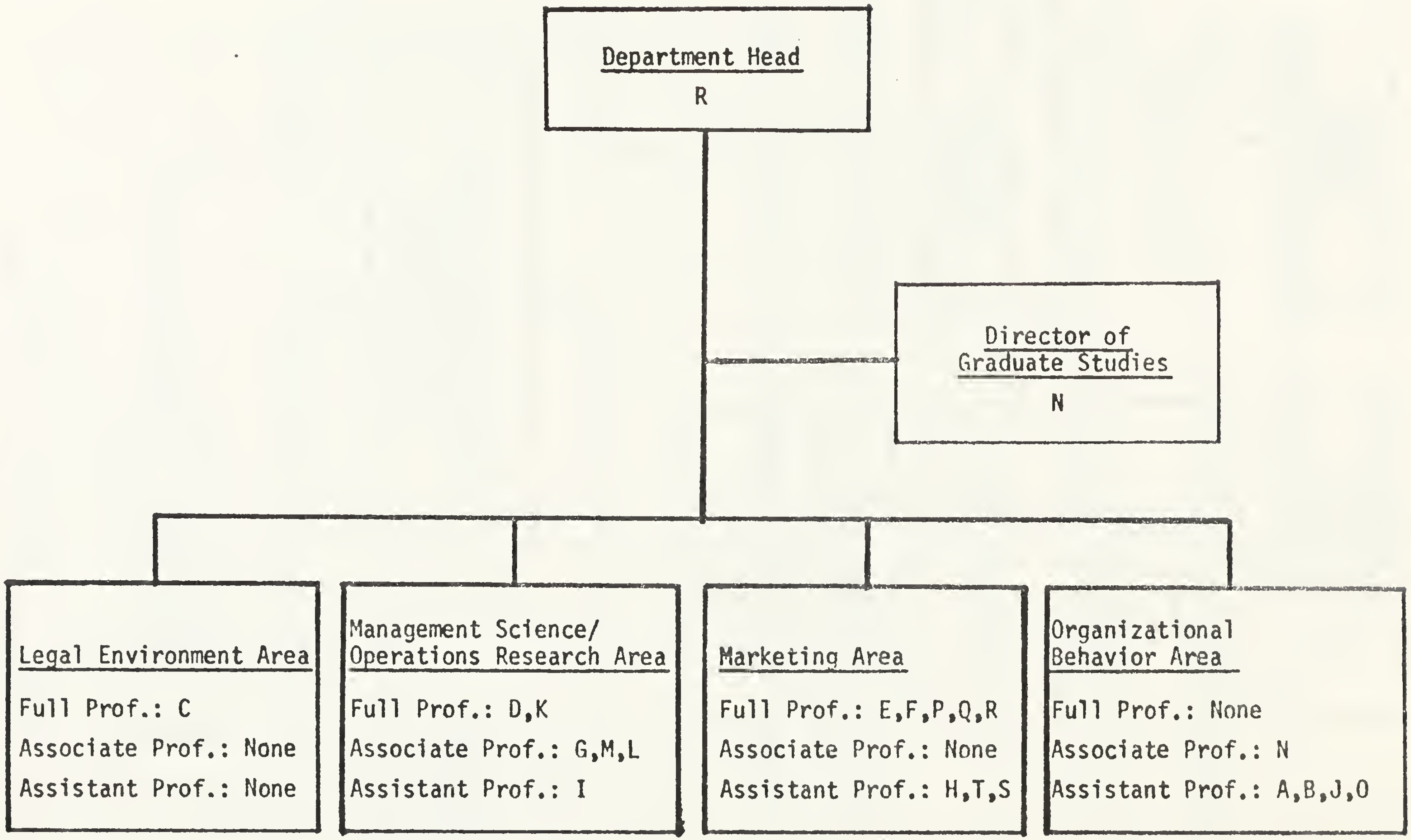


Figure 2. The codified formal structure. (The letters denote all faculty members included as stimuli.)

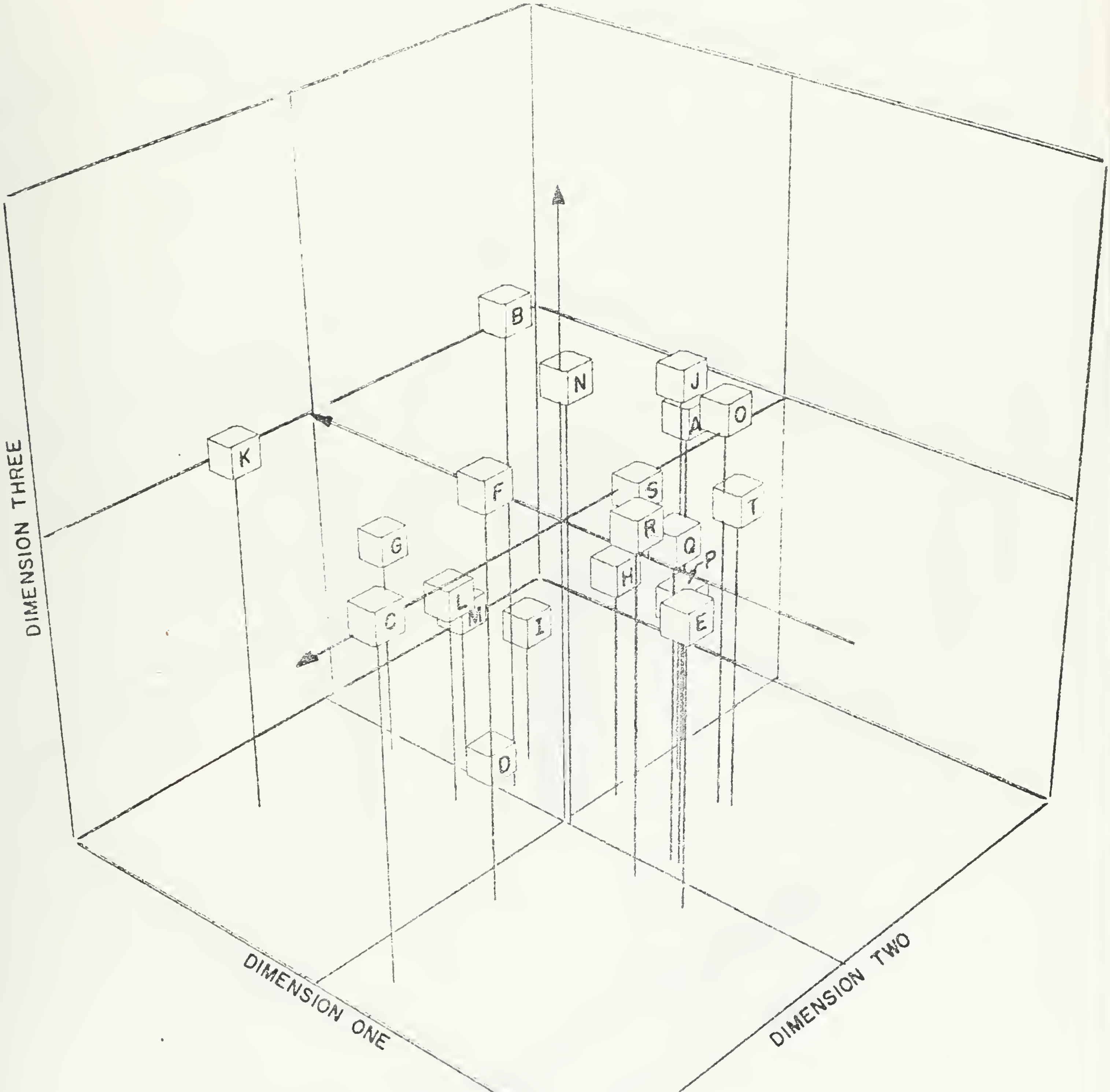


Figure 3. MDS representation for the Total Group.

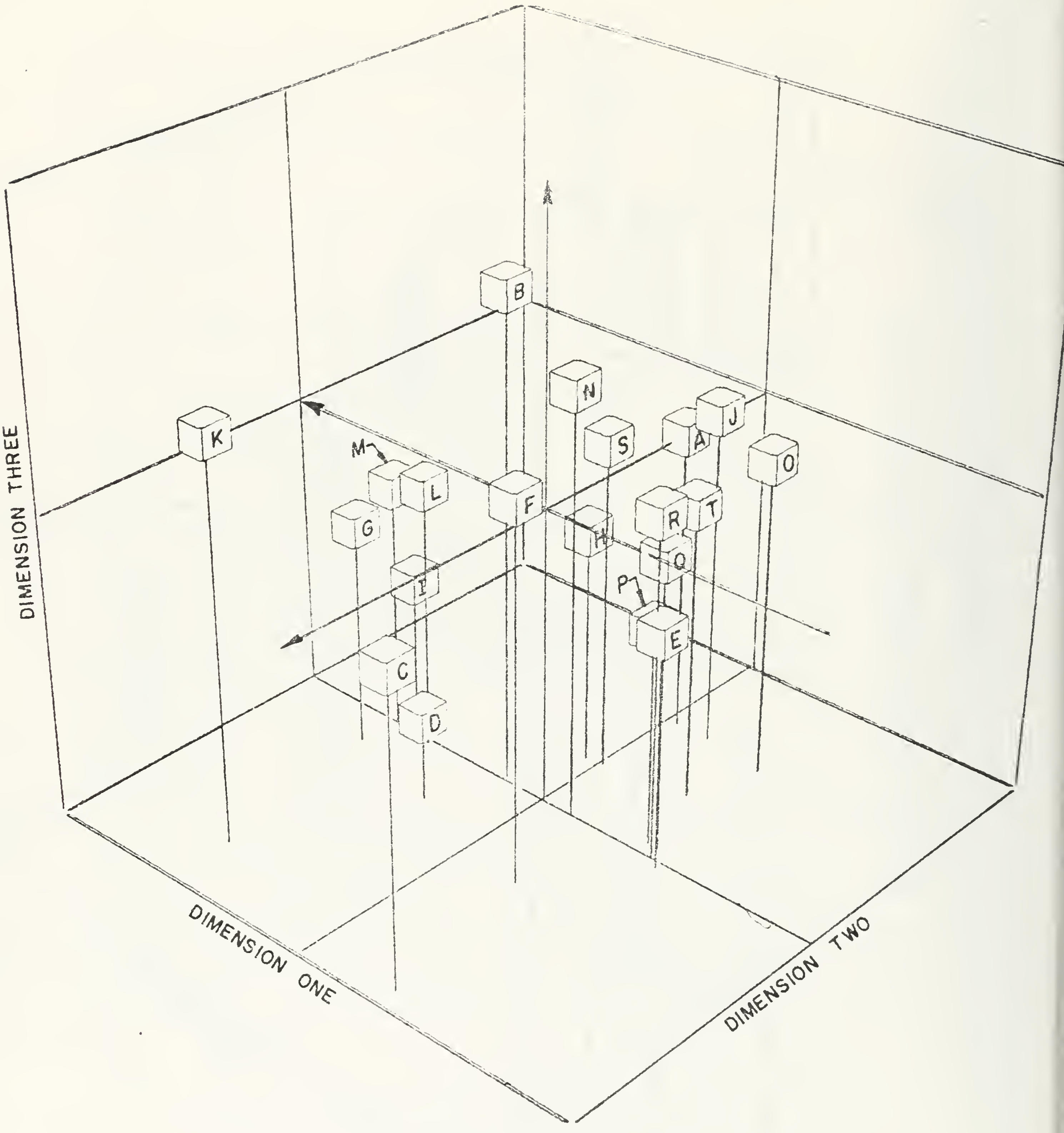


Figure 4. MDS representation for Group 1.

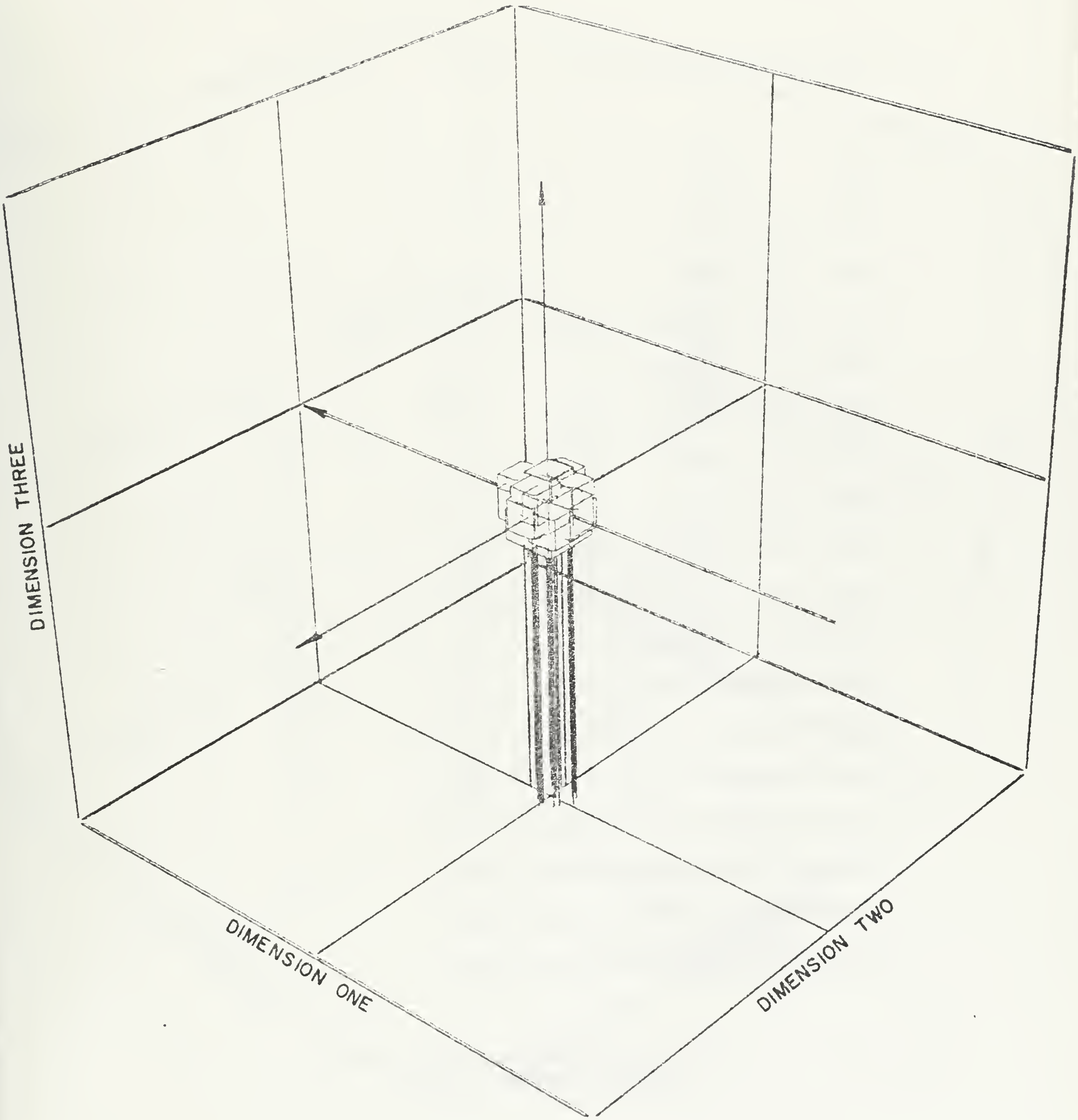


Figure 5. MDS representation for Group 2.

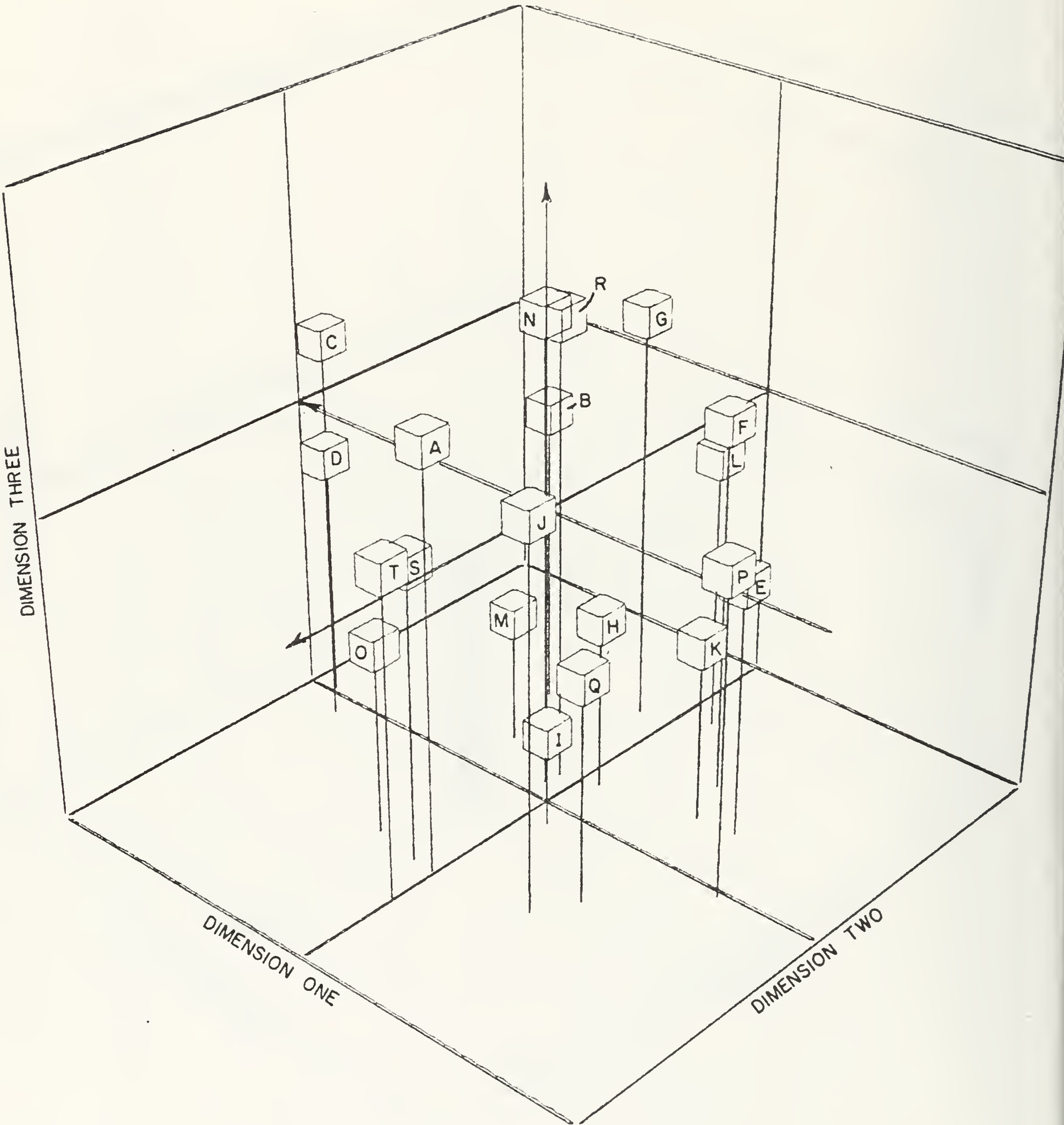


Figure 6. MDS representation for Group 2 with expanded scale.

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       Stimulus Person    C B K D G I L M F N S P E Q A J O H T R

Row  1                    . . . . . . . . . . . . XXX . . . . . .
     2                    . . . . . . . . . . . . XXX . . . . XXX
     3                    . . . . . . . . . . . . XXX . XXX . XXX
     4                    . . . . . . . . . . . XXXXX . XXX . XXX
     5                    . . . . . . XXX . . . XXXXX . XXX . XXX
     6                    . . . . . . XXX . . . XXXXX . XXX XXXXX
     7                    . . . . . . XXX . . . XXXXX XXXXX XXXXX
     8                    . . . . XXX XXX . . . XXXXX XXXXX XXXXX
     9                    . . . . XXX XXX . XXX XXXXX XXXXX XXXXX
    10                    . . . . XXXXXXX . XXX XXXXX XXXXX XXXXX
    11                    . . . . XXXXXXX XXXXX XXXXX XXXXX XXXXX
    12                    . . . . XXXXXXX XXXXX XXXXX XXXXXXXXXXX
    13                    . . . . XXXXXXX XXXXX XXXXXXXXXXXXXXXXX
    14                    . . . XXXXXXXXX XXXXX XXXXXXXXXXXXXXXXX
    15                    . XXX XXXXXXXXX XXXXX XXXXXXXXXXXXXXXXX
    16                    XXXXX XXXXXXXXX XXXXX XXXXXXXXXXXXXXXXX
    17                    XXXXX XXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXX
    18                    XXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    19                    XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
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Figure 7. Cluster Analysis for Group 1 (HCS, diameter method).