Multidimensional Scaling: High-Tech Sociometry for the 21st Century

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ABSTRACT. Multidimensional scaling (MDS) has been available since the 1950s, but it has not received widespread recognition in sociometry. In this article, the authors briefly trace the history of MDS and explain why MDS has been used infrequently in sociometry; they then illustrate how it can be used effectively as a diagnostic intervention for management consulting. A case is made for greater application of MDS as a diagnostic and intervention strategy with small groups. The authors predict that MDS will be the high-tech sociometry for the 21st century.

ALMOST EVERYONE WHO DEFINES multidimensional scaling (MDS) applies a slightly different emphasis. We have selected three definitions from the literature that represent numerous variations. With reference to MDS's application to counseling research, Davison, Richards, and Rounds (1986) used the following definition: "Multidimensional scaling (MDS) is a statistical technique that can be used in mapping the structure of objects as they are perceived by clients and counselors" (p. 178). Leblebici, Marlow, and Rowland (1983) define MDS as follows: "In very general terms, multidimensional scaling (MDS) can be described as a family of geometric models for multidimensional representation of data, and a corresponding set of methods for fitting such models to actual observations" (p. 167). And, finally, Young and Hamer (1987) state:

> The term *multidimensional scaling* refers to a family of data analysis methods, all of which portray the data's structure in a spatial fashion easily assimilated by the relatively untrained human eye. That is, they construct a geometric representation of the data, usually in a Euclidean space of fairly low dimensionality. Some multidimensional scaling methods display the data structure in non-Euclidean spaces, and some methods provide additional information about how the structure varies over time, individuals, or experimental condi-

> tions. The essential ingredient defining all multidimensional scaling methods is the spacial representation of data structure. (p. 3)

Young and Hamer (1987) divide the history of MDS into four stages, roughly equated in decades.

1. The first decade was heralded by the seminal work of Torgerson (1952), who defined the multidimensional scaling problem and provided the first metric solution.
2. The second decade of work was ushered in by the path-breaking work of Shepard (1962) and Kruskal (1964) on nonmetric multidimensional scaling and saw the highly illuminating work of Coombs (1964) on data theory.
3. The third decade opened with the trend-setting work of Carroll and Chang (1970) on individual difference multidimensional scaling and saw the consolidation of the preceding 25 years of developments by Takane, Young, and de Leeuw (1977) and by de Leeuw and Heiser (1980).
4. The decade of the 1980s witnessed the development of maximum likelihood multidimensional scaling, as exemplified by Ramsey (1982) and Takane (1980a, 1980b). (p. 15)

Young and Hamer (1987) view MDS as appearing to reach full maturity in the "family" of scaling methods. They project future growth through computer analysis and nonlinear scaling methods, and perhaps as important as new methods is the potential of high-resolution three-dimensional color graphics displays that allow interaction in real time and that are based on quantitative analysis of qualitative data (scaling).

MDS Applications to Sociometry

Noma and Smith (1985) refer to Moreno's (1934) sociograms as "ad hoc placement of individuals in space" (p. 180). Collins (1987) refers to sociometry as "the study of interpersonal relations within groups" (p. 179). She contends that usually the social interaction network is summarized in a sociogram, but she argues that, because the sociogram is not entirely empirically derived, objectivity and formality are lacking. Although Collins (1987) agrees that the sociogram has great descriptive power, she also believes that it "may in some cases fall short as a valid representation of the interaction pattern of the data" (p. 180).

To alleviate some of the subjectivity surrounding the sociogram and traditional sociometric practices, Collins suggests using a more formal technique for spatially representing a set of stimuli—MDS. Collins reports, however, that there have been few attempts to apply MDS to sociometric data. She cites Laumann and Guttman (1966) as perhaps the first to use

MDS with sociometric data, but even then it was not applied to typical sociometric problems. Laumann and Guttman's study sampled city-dwellers continuity among occupations rather than among persons. A pioneering study by Jones and Young (1972), according to Collins, was much closer to the mainstream of sociometric research. They used the individual scaling model (INDSCAL) to study the similarity of all possible pairs of members of an academic department. Even though the Jones and Young study was similar to more traditional sociometric analyses, it did not generate many related applications. Collins reasoned that research studies did not follow because many sociometric studies are done in classrooms, especially with young children, and even in a small classroom of 15 the children would be required to rate 105 stimulus pairs, an effort that would fatigue them. The complexity of the task, that is, judging similarity among all classmates, would also present a significant challenge to young children. Although there have been few applications of MDS to sociometry for reasons suggested by Collins, many opportunities exist that are virtually untapped. We will refer to some of these later in this article.

Advantages and Disadvantages of MDS

No attempt is made here to include a comprehensive listing and analysis of advantages and disadvantages of MDS. We include only the more relevant issues and those that pertain to the case examples that follow.

Perhaps the most intriguing and advantageous aspect of MDS for assessment purposes is its innocuousness, or noninvasiveness. When a person is asked to compare other persons (paired-group members) simply on the basis of their similarity/dissimilarity to each other, the rater can use any and all dimensions/characteristics that he or she chooses. Therefore, there is no bias introduced by the person (external evaluator/consultant) doing the assessment. Following the use of their own criteria for comparing each other, the raters are then presented with a picture/map generated by the MDS computer program showing how the ratings/comparisons of everyone positions individuals in two-dimensional space. Based on the groupings alone, the subjects can be asked to interpret what the groupings represent to them. In other words, the subjects can be totally involved in determining the nature of the input and interpreting the output. To assist in the interpretation of the groupings/dimensions of the MDS configurations or maps, researchers can give unidimensional measures such as adjective checklists to subjects concurrent with their MDS-paired ratings.

The process begins with a very subjective subject rating followed by an objective statistical analysis and usually concludes with a subjective analysis by participants. The subjective analysis, however, can be corroborated

by correlational analyses, the use of participant weights, and fit measures (Davison, Richards, & Rounds, 1986).

MDS programs can quantify both metric and nonmetric data, unlike factor analysis, which requires metric data. MDS solutions usually require fewer dimensions than factors from factor analysis; therefore, graphic representations are simpler (Davison, 1985).

The advantages of MDS also frequently can pose disadvantages. For example, because the subject rater uses his or her own dimensions for rating, typically some type of unidimensional scale is often administered to aid the subject raters in interpreting the maps that are generated.

Another major disadvantage of MDS is related to the size of the sample. Fewer than 9 or 10 participants for two-dimensional solutions and fewer than 14 or 15 for three-dimensional algorithms such as INDSCAL are general rules of thumb to follow (Shoben, 1983). As cited earlier, children develop rating fatigue with large numbers (15 class members generate 105 paired comparisons) and are confused by the complexity of rating each other on similarities/dissimilarities. Adults also become bored and fatigued when groups become larger than 10 or 12. Generalization of research results depends upon randomness of sampling, and, because groups must be small, generalization of results may be restricted.

A disadvantage of having subjects interpret their own maps is that if some subjects are shown to be isolates/rejects, it may be difficult to conceal the fact, and unhealthy emotional responses may be generated. Care must be taken by the leader to protect isolated group subjects.

Application of MDS to Management Consulting

MDS has numerous and varied applications. Our purpose in this article is not to review these applications but rather to single out its unique application to management consulting and to illustrate this application with two case reports. Other applications and references can be found, for example: vocational, family, and group counseling (Buser, 1989; Davison, Richards, & Rounds, 1986); stereotype research (Funk, Horowitz, Lipshitz, & Young, 1976); vocational psychology (Rounds & Zevon, 1983); leadership behavior (Jones, 1983); supervisor roles (Ellis & Dell, 1986); organizational structure (Leblebici, Marlow, & Rowland, 1983); counseling psychology (Fitzgerald & Hubert, 1987); marriage counseling (Diekhoff, Holder, & Burks, 1988); small groups (Gazda & Mobley, 1981; Stanton & Morris, 1987); family counseling (Bisio, 1987; Mobley & Gazda, 1981).

Several textbooks are also available: The *User's Guide to Multidimensional Scaling* (Coxton, 1982), *Multidimensional Scaling* (Davison,

1983), *Multidimensional Scaling* (Kruskal & Wish, 1978), *Introduction to Multidimensional Scaling* (Schiffman, Reynolds, & Young, 1981), and *Multidimensional Scaling: History, Theory, and Applications* (Young & Hamer, 1987).

Company A

As a community-oriented manufacturing company, the changes and decisions made at Company A frequently had repercussions in their city. Their parent company strongly encouraged companies to be involved in their respective regions and allocated for diversity at all levels of the company. Because of the demands of its product, the staff of about 500 in this operation were probably better educated than those at most other state plants. At this location, the president has a vice-president with two directors and a general manager with seven directors. Together these 12 managers formed the executive committee of that company.

At Company A, we were invited to provide some feedback, team building, and direction because the organization had experienced the loss of its general manager (GM), the number two person in the organization, to whom most of the staff reported. Although the GM had made some bold changes and was responsible for four people being in the positions they were in as managers, the GM had also created a culture in which fear led to memo writing to protect oneself. The president of the organization had numerous responsibilities that took him out of the facility on a regular basis, leaving the GM to manage the day-to-day operations. The president relied on the GM for his information regarding almost all aspects of the organization. Without the GM in the strategic position between the president and the managers, the entire culture was now ill-defined. Our mission was to bring definition to the re-ordered structure, which would have the managers reporting to the president, and to encourage behaviors from the president that would reverse any negative tendencies that the organization had developed. With the numerous uncertainties that the situation manifested, the MDS evaluation seemed to be ideal because of its noninvasive quality.

All members of the executive committee (manager or higher management) were included in the MDS evaluation; their names were listed on the evaluation form, and they were given a form to complete. When these 12 people had returned their rating sheets, the *SAS* ALSCAL program for individual differences multidimensional scaling (see chapter 9 in Schiffman, Reynolds, & Young, 1981) was used to provide a two-dimensional graphic of the *perceived* relationship among these upper level managers. The human resources director worked with the consultant

to name the two dimensions, with an opportunity for the president and vice-president individually and the group as a whole to confirm or adjust these dimensions (see Figure 1).

The *X* axis (Dimension I) seemed to indicate a paradigm of goal-oriented, hard-driving people on the left-hand side and more detail-oriented people on the right side. The president and the vice-president were on the left, whereas some support staff people were on the right, including management information systems, accounting, and marketing. Human resources and sales managers were in the middle on these two dimensions. Although the group was not perfectly satisfied with the placements, there seemed to be consensus that they could at least understand this placement. The second dimension seemed to express the group perception of the personality

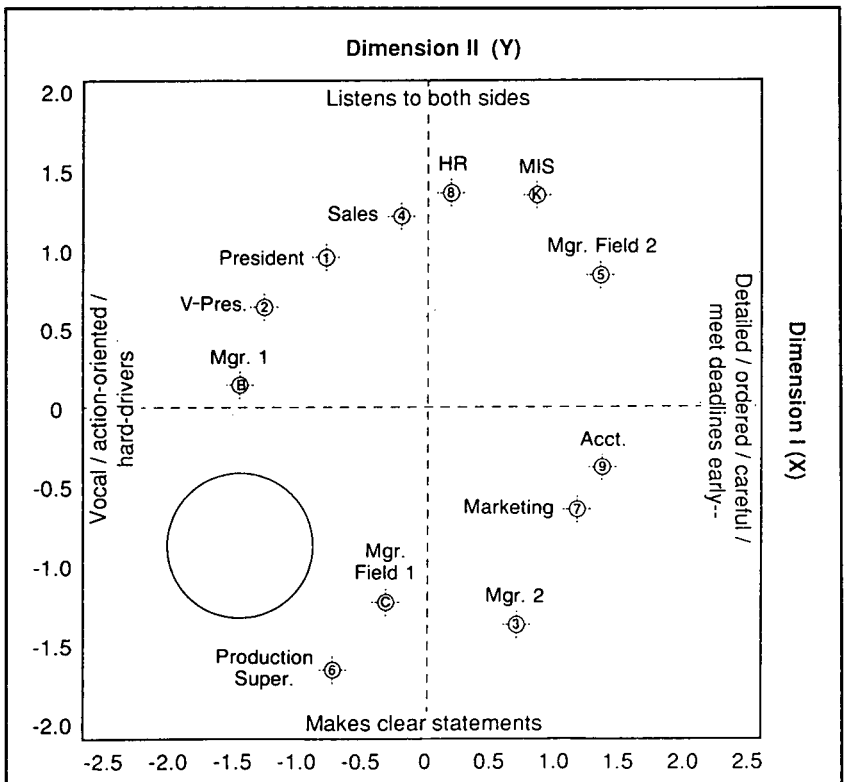

FIGURE 1. Company A initial MDS group solution with all managers

of the individual manager. The upper part of the *Y* axis reflected perceptions about whether or not the manager would listen to both sides; the bottom part of the graphic reflected perceptions concerning the manager's propensity to state a clear position. It was noted that the human resources person scored the highest in listening to both sides—a favorable place to be for that person and function. Although not extreme, both the president and vice-president were perceived as being in a listening posture during this period of getting reconnected to the managers. This style was supported by the consultant. The strongest disagreement with this axis came from one of the managers (production supervisor) who paradoxically took a strong stand. He said that maybe other people did not recognize it, but he spent a lot of time listening. This opportunity was used to explain again the difference between perceptions by group members and "reality."

This MDS assessment had an interesting feature that was discussed in both the individual and group sessions for confirmation. The managers were positioned on these two dimensions in a rough circle around the origin. However, note the lower left quadrant. For the consultant, it seemed that a person was missing between number 6 and B. In each of the two sessions, the consultant posed the question: "Would you be comfortable describing your former general manager as an action-oriented person who tended to take clear stands?" In each case, the response was in the affirmative. At that point, the 12 members could not consider themselves without including the GM, who was no longer part of the group. The former structure was still in place even though one of the members had been removed. The premise for the consultation, redefining the organization without the powerful GM, seemed to be strongly supported from the MDS sociometric.

Once the group solution had been established, each of the group members who completed rating sheets (in Company A, all managers were included) could then be assessed by the ALSCAL program for their individual correlation with Dimension I and Dimension II. How well those gestalt issues fit them individually could be explained by this analysis (see Figures 2 and 4). The higher the correlation of the individual with the group dimensions, the better the individual could understand and function in that environment, and vice versa.

The correlations from individual differences analyses for this two-axis solution were not as high as the consultant would have liked. Only one of the correlations between the individual's perception of the members and the composite picture was over .5 (see Figure 2). Fortunately for the consultant, the person who scored highest on both dimensions was the human resources director, with whom the consultant was working most closely. This low correlation of the individuals with the group model suggested that some of the managers were experiencing a different culture from their col-

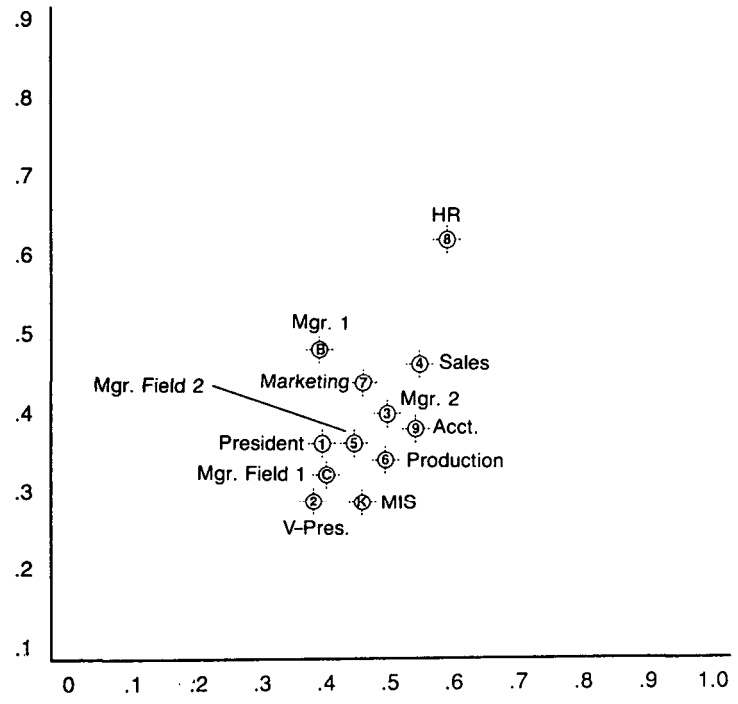

FIGURE 2. Individual correlations: Company A managers with initial MDS group solutions.

leagues. All of the managers except two had reported to the GM. Those two managers reported to the vice-president, who reported directly to the president. It seemed plausible that the experiences of those two managers could have been quite different from the other eight and therefore were not as critical to accomplishing the mission of this consultation as were those who were directly affected by the GM.

We re-assessed the data, omitting both the perceptions of the vice-president and his two reporting managers and all of the ratings that had to do with them. In the new solution (Figure 3), six of the nine managers had individual differences correlations over .5 on at least one of the dimensions. Something significant had happened to move the president out of his position of being clustered with the other managers in the first assess-

ment (Figure 2) to the position of being totally isolated from the other managers in the second assessment (Figure 4).

The president's correlation to the *X* axis was .8, very high, but his correlation to the *Y* axis was .2, very low. The second assessment (listens *vs.* takes stands) indicated that the president had a clear picture of what the first dimension represented but no picture at all of what the other managers were dealing with on the second dimension (yet to be determined).

The information reflected in Figure 4 is very different from that of the first solution. Placement of the managers along Dimension I in this second solution looks a lot like their placement along Dimension II in the first solution. The production supervisor who did not like his role as a person who takes stands rather than listens is still on the extreme. The president is

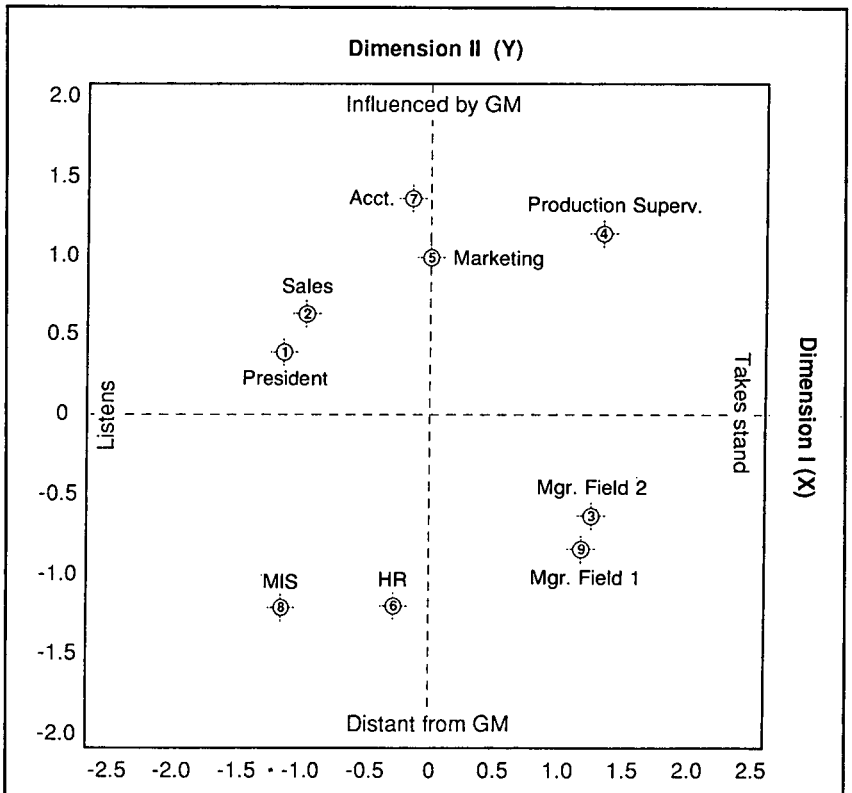

FIGURE 3. Company A MDS group solution (omitting the managers who did not report to the general manager)

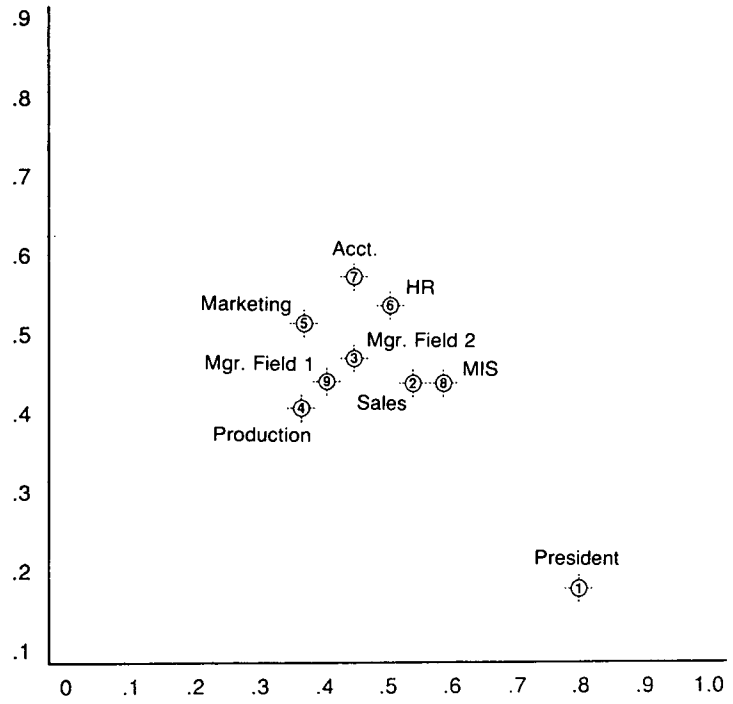

FIGURE 4. Individual correlations: Company managers with Company A reassessment

approximately where he was before. The human resources (HR) manager is in a more moderated position, according to this composite, than in the first one that included people who were outside the immediate functioning of this group of managers. As the president's low correlation suggests, Dimension II in Figure 4 bears no resemblance to either of the dimensions in the first solution.

The second most important thing underlying the perceptions of this group of people who reported to the GM is different from any dimension determined thus far. Being a hard driver or being conscientious with details is not as important as some other issue. In individual sessions with the HR manager, the president, and the vice-president and finally in sessions with the full group, the label that emerged on the new *Y* axis was people

who were influenced by the GM (top) versus people who were distant from the GM (bottom). In other words, this dimension was about how the managers negotiated their relationship with the GM. The president had been unable to perceive this dimension because of his unique relationship with the GM and his insulation from the managers. If the president is to make sense of where the organization is now without the GM, then he is going to have to understand this dimension and develop individual relationships with the GM's former managers.

Creating an environment in which it would be safe to provide feedback and one in which the managers' feedback could be used to bring the president up to speed on the reality within the organization became the focus of the consultation. In three group sessions and as many individual sessions with the president, the organization was coached toward a new culture, a culture that addressed those potential conflicts openly and directly. After a year, the vignettes of successful applications among these managers have continued to be reported and are trickling down through the organization. MDS had powerfully focused the consultation on the organization's and leadership's challenge in a nonobtrusive manner.

Company B

Company B was a subsidiary of a multinational manufacturing company. Through a series of operations, it moved raw materials to customers for retail sales. The senior managers included in the weekly staff meetings involved three different levels: president (senior officer at that location); three vice-presidents (development, procurement, production/sales); and area managers (two plant managers; a sales manager; management information systems manager; accounting manager; and human resources manager).

As a follow-up to their continuous improvement (CI) efforts, Company B brought us in as consultants to understand the underlying issues that were shaping their interactions. The MDS analysis was elected as an evaluation procedure. All of the upper level managers at this particular location were included in the assessment, both as evaluatees and evaluators. Everybody participated in the study. (If, for some reason, a person or several persons did not complete the rating sheets, the composite picture still could have been created, and the group solution could still have been created; however, the individual assessment for those nonparticipants would not have been possible. Obviously, the more group members who participate, the more who complete the solution.)

When the MDS sociometric was reviewed with the president (Figure 5), the recognition of the dimensions and the relationships among the man-

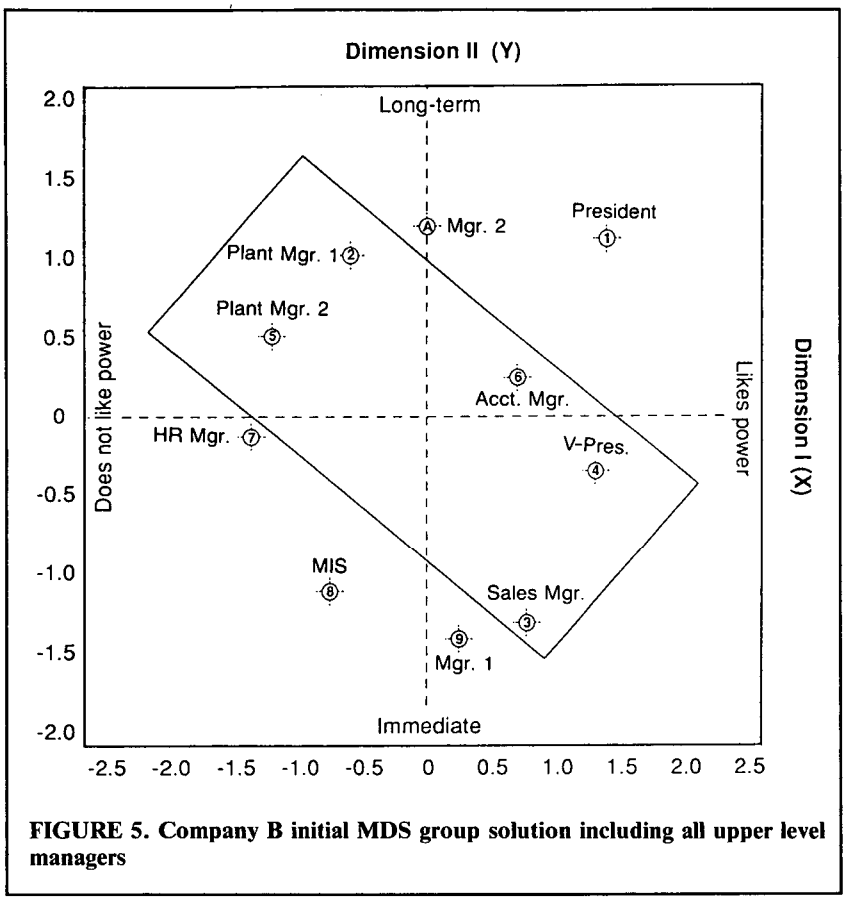

FIGURE 5. Company B initial MDS group solution including all upper level managers

agers was mixed. The *X* axis seemed to be about power: Those on the left did not like power and those on the right did. The *Y* axis seemed to be about vision: Those toward the top had a long-term view, whereas those on the bottom were more immediate in their perspectives. On both of the axes, however, there were discrepancies. What was the accountant (#6) doing over on the power side? Hence, the label was changed from "has power" to "likes power." The two plant managers, who were located in the "does not like power" of the *X* axis, did not seem well placed at that extreme. On Dimension II, the sales manager, who does long-term forecasting, was identified more with the extreme of functioning on a short-term perspective, as was the raw materials manager (#9), whose perspective often had to span decades. The picture was clear enough for one of

the plant managers to name the four quadrants: the upper left he called "operators," the upper right—"decision makers," the lower right—"people runners," and the lower left—"support staff." At the same time, there was enough ambiguity about the dimensions that one of the support staff (#8), a number cruncher, questioned the validity of the MDS process. (Rule: Business people do not like ambiguity. They want answers/solutions. They are not interested in the process.)

As was the case with Company A, the limitation of this solution and the progress of their CI program might have been indicated by the individual manager's correlations to the group analysis. The correlations between the individual managers and the group solution (see Figure 6) ranged from .2 to a high of .6, with .4+ occurring at the highest frequen-

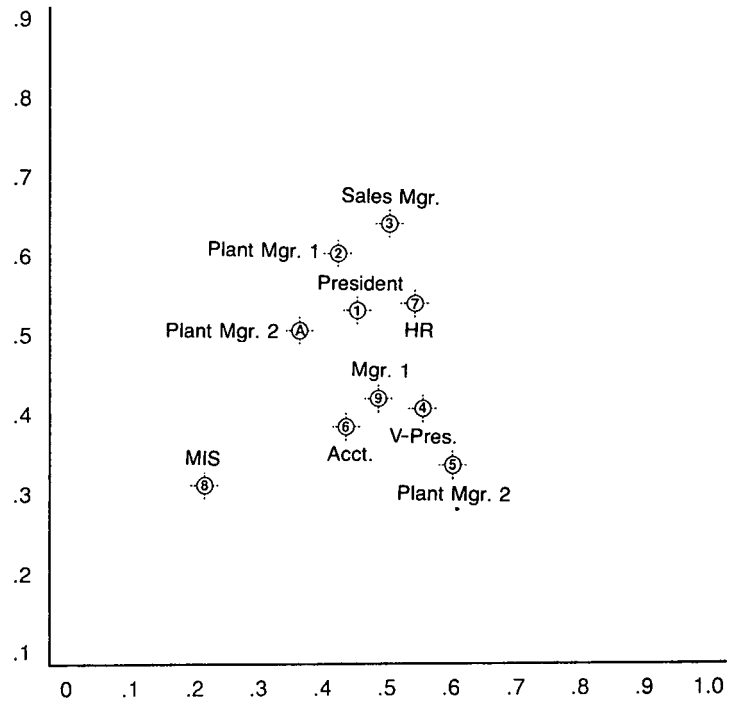

FIGURE 6. Individual manager correlations with the initial MDS group solution in Company B

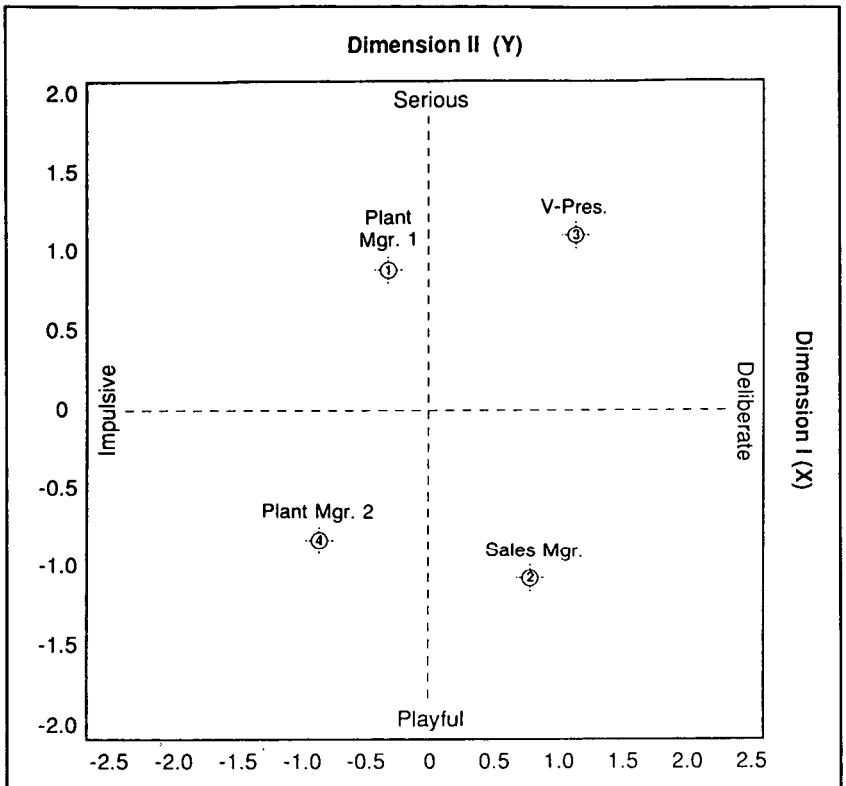

FIGURE 7. Company B initial MDS group dimension I (X) solution including vice-president and his subordinates

cy (six times). The diversity of the functions of these upper-level managers could have been causing the lack of unity in the underlying important issues. Because of their differences in roles, the overall group picture was not consensual. Maybe their subgrouping and diverse functions caused them to perceive the larger group differently while sharing a unified perception within their specialty. A clear perspective on meshing their diverse functions into a common mission was suggested as a reason for this lack of unified perception. Some exploration into subgrouping was thought to be clarifying.

Upon closer scrutiny, it did appear that the president's team was really three subteams. The president had three people directly reporting to him: two vice-presidents over raw materials managers and a vice-president

over production and sales. The plant managers and sales manager were part of the vice-president's team. The support staff for human resources and accounting had a dual report structure that included responsibility not only to the president on location but also to the head of their specific staff function at corporate headquarters. The production/sales vice-president's (VP's) staff, who complained the most about the consultation and this evaluation, seemed to be the most different from those managers who reported directly to the president.

To achieve a more focused picture of this organization, we assessed the VP's team separately from the rest of the president's team. Then, personnel reporting directly to the president were analyzed together. Please note that this reassessment did not involve more time and effort by the company or these managers: The consultants reorganized the existing data.

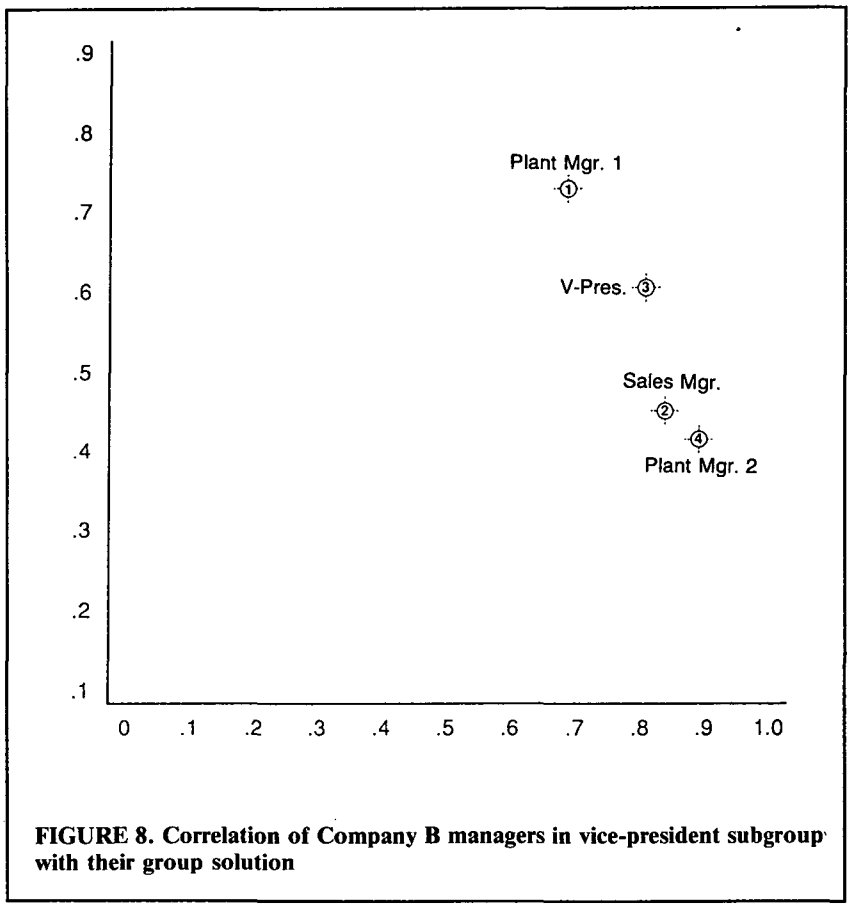

FIGURE 8. Correlation of Company B managers in vice-president subgroup with their group solution

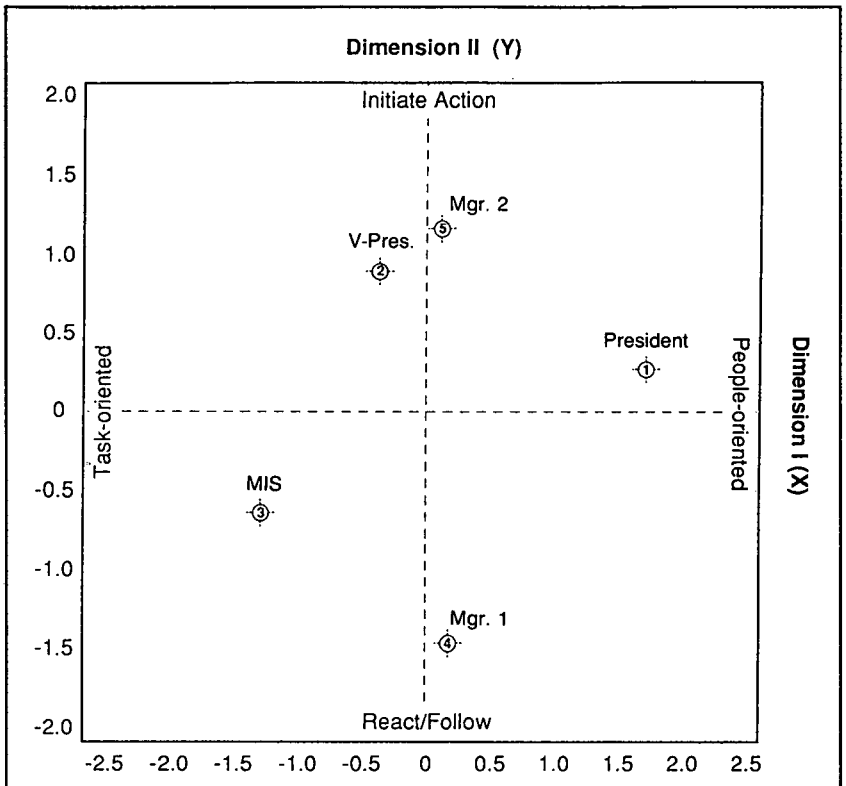

FIGURE 9. Company B initial MDS solution including president and only his direct subordinates

The production/sales VP and the three persons reporting to him formed a quadrilateral (see Figure 7) that mirrored their relationships in Figure 5. They had solidarity on their two-dimensional solution (see Figure 8 and note the high individual correlations to these dimensions). The VP was not on the extreme in the individual differences solution, suggesting that he was able to understand his managers, who emphasized either extreme—a good position to be in.

When this VP's rectangular subgroup was removed from the president's team, another unified subgroup was revealed. The existence of this subgroup was further emphasized when the dual reporting support staff was omitted (see Figures 9 and 10). With the exception of the MIS manager, everyone was committed to Dimension I, people-oriented versus task-ori-

ented. Although the president and vice-president understood this dimension (Figure 10, individual differences assessment), they were perceived as opposites in their management styles on this dimension (Figure 9): the people-oriented president versus the task-oriented VP.

Based upon this MDS assessment, the president had at least two teams to whom he related: the managers who report directly to him and the managers who report to his VP. Another subgroup of support staff could also be described. The cultures and underlying issues were different among these groups. A similarity between the president's group Dimension II, initiate/act versus react/follow, and the VP's group Dimension I, impulsive versus deliberate, may exist but cannot be assumed. The same could be true for people- versus task-oriented and playful versus serious for the re-

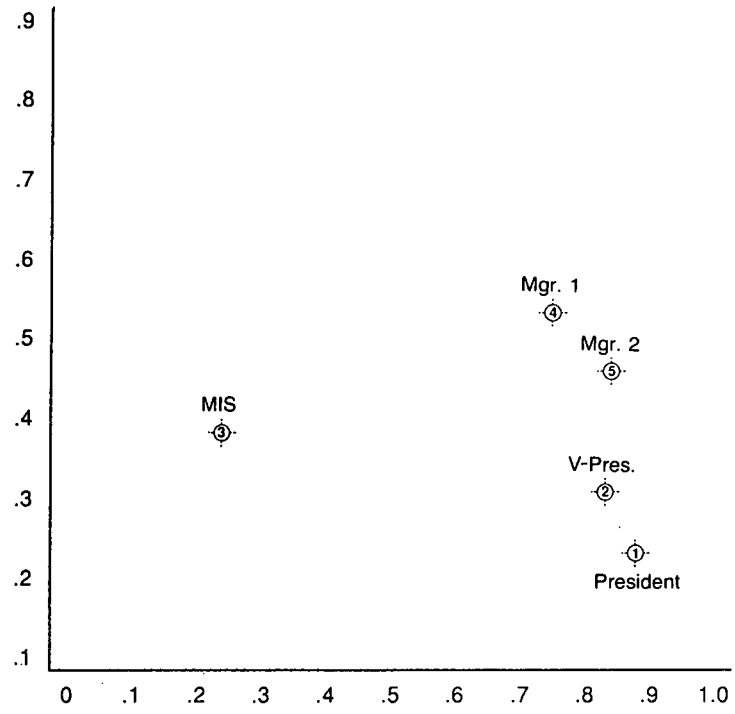

FIGURE 10. Individual correlations: Managers, president, and his subordinates with their MDS group solution

spective groups. But the overall solution (Figure 5) suggested that a meaningful difference was occurring between subgroups. The president and anyone else operating in both groups needed to respect the differences among these groups and not expect the same response from them.

The task of the consultation became that of having the president clarify his mission in a way that could bring together the diverse interests/perspectives of his subgroups, thereby enhancing his CI project. His relationship and boundaries with the VP were critical in affecting the VP's subgroup. By coaching the president individually over 2 months, a meaningful alignment of the subgroups was begun.

Conclusions

From the foregoing presentation, a couple of generalizations may be warranted. First, because of the high technology of computers and the subsequent development of scaling models, a more sophisticated form of sociometry became available that seems to have great promise for expanding sociometric applications. The original enthusiasm for MDS in sociometry abated when it was discovered that many, if not most, sociometric applications were done with children in school classrooms, neither of which lend themselves well to MDS. First, children have difficulty understanding how to rate one another on a metric scale regarding perceived similarities and differences between and among each other. Second, unless random sampling is done, classrooms of 25–30 are too large, because the system of comparing every student with every other student would lead to several hundred ratings, with subsequent student-rating fatigue.

Although MDS has its limitations when applied to young children and large groups (over 15), there are numerous applications of a sociometric nature that lend themselves well to MDS. The authors have used MDS quite successfully with families, group counseling and psychotherapy, and management consultation and conflict resolution. We have described the latter in this article. We believe that MDS holds great promise for use in studying small-group processes, for diagnosis of small-group dynamics that are either facilitative or debilitating, and for providing a "road map" for change. These advantages of MDS were illustrated in the case examples of Companies A and B described in this article.

It is premature for reasons already cited to assume that MDS will replace traditional sociometry, but it is certainly replete with opportunities to expand upon and provide greater objectivity to sociometry. We predict that MDS will be the basis for application of sociometry in the 21st century.

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