"THE ROBUSTNESS OF MDS CONFIGURATIONS IN THE FACE OF INCOMPLETE DATA

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N° 87 / 25

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Director of Publication :

Charles WYPLOSZ, Associate Dean
for Research and Development

Printed by INSEAD,
Fontainebleau, France

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March 1987

Revised July 1987

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ABSTRACT

This paper examines the robustness of MDS configurations where incomplete rather than complete input data are used. Using two empirical studies, the authors show that robustness varies as the amount of incomplete data increases and that random methods of data deletion perform as well as cyclic designs. These findings provide empirical support for earlier Monté Carlo literature on the topic. It is also shown that individual characteristics of respondents, namely cognitive integration and imagery, have an influence on the quality of configurations obtained with incomplete data.

THE ROBUSTNESS OF MDS CONFIGURATIONS IN THE FACE OF INCOMPLETE DATA

Multidimensional Scaling (MDS) algorithms have been available for more than two decades, and the large number of published applications attests to their popularity and usefulness. In practical applications, the users of MDS are often confronted with large numbers of stimuli for which proximity judgments need to be obtained from the respondents (Green and Carmone 1970; Green and Rao 1972; Rao and Katz 1971). Since these judgments are frequently obtained in the form of paired comparisons, the respondent task increases multiplicatively (n x (n-1)/2) with the number of stimuli. This often detracts researchers from exploring the use of multidimensional scaling due to labor and cost of obtaining such information. What is perhaps more important is the likelihood that with the increase in the number of stimuli the task may quickly become unmanageable. Respondent fatigue, disinterest, and information overload may combine to produce data of questionable reliability and validity.

Many scholars (e.g., Spence 1983; Young and Cliff 1972) have suggested that not all proximity judgments are essential for the recovery of the "true" perceptual space.[1] Some judgments may contain redundant information and hence may be excluded without appreciable loss of accuracy. Indeed, the idea that incomplete data can be substituted for complete data and still yield "acceptable" MDS configurations is very attractive, particularly for applied research. However, there is little empirical evidence to support this view and to guide the researcher in answering the following three, related questions: a) can some proportion of the data be treated as incomplete or accepted as missing without substantially altering the configurations that would result from using the full data set? b) assuming that a certain amount of input data can be ignored, what is the best data deletion method to use? c) are there individual differences which systematically impact configuration recovery in MDS models with incomplete data? Two empirical studies were undertaken to examine these questions. They are described in the following.

PRELIMINARY STUDY

Background and Hypotheses

Monté Carlo studies of MDS configuration recovery have consistently provided support for the rather intuitively obvious view that configuration recovery becomes poorer as the proportion of missing data increases (e.g., Graef and Spence 1979; Issac 1982; MacCallum 1979; Spence and Domoney 1974). However, recovery remains good provided the level of error in the data is low. Given that the MDS data which applied researchers in marketing are typically confronted with are bound to contain a certain amount of error, this issue merits further investigation using empirical rather than simulated data. For example, MacCallum and Cornelius (1977, p. 426) state in their suggestions for further research, "a fourth area of research would involve empirical investigation rather than Monté Carlo studies. Since the amount of error in the data has been shown repeatedly to be the most important factor in the goodness of multidimensional scaling solutions, a series of empirical studies .... could prove of great practical value to users of multidimensional scaling models".

A related issue is the impact of the particular procedure used for deleting data on configuration recovery. Past studies of the recovery properties of alternative methods for reducing large data sets have been centered on the use of cyclic designs versus designs based on random deletions. A cyclic design is a particular type of partially balanced incomplete block design (Spence and Domoney 1974). It has the property of being balanced and connected, i.e. in the subset selected every stimulus appears equally often and the set is not divisible into two or more subsets in the sense that no comparisons are made between objects in one set and objects in the other. Methods for constructing cyclic paired comparison designs have been described in statistical literature (e.g., Clatworthy 1973; David 1963; John, Wolock and David 1972). Since many marketing researchers are not likely to be familiar with these designs, a simple method for constructing these designs which has been proposed by David (1963) will be presented and illustrated.

1. Number the stimuli 0, 1, 2, ..., n-1.
2. Consider the cyclic sets

   $\{s\}$: (0,s) (1, s+1), ... (t, s+t) ... (n-1, s+n-1)

   with reduction modulo n where necessary, i.e., the remainder after division by n. S can take values 1, 2, ..., n-1. Each cyclic set contains n pairs of stimuli. Each stimulus appears equally often. The set is connected if s is relatively prime to n.
3. Combine the desired number of cyclic sets to form a cyclic design.

Example: For n = 10 stimuli, the following cyclic sets may be generated:

{s=1}:	(0,1)	(1,2)	(2,3)	(3,4)	(4,5)
	(5,6)	(6,7)	(7,8)	(8,9)	(9,0)
{s=2}:	(0,2)	(1,3)	(2,4)	(3,5)	(4,6)
	(5,7)	(6,8)	(7,9)	(8,0)	(9,1)
{s=3}:	(0,3)	(1,4)	(2,5)	(3,6)	(4,7)
	(5,8)	(6,9)	(7,0)	(8,1)	(9,2)

These sets are illustrated in Figure 1. It should be noted that set {s=2} is not connected as 2 is not relatively prime to 10. As illustrated in Figure 1, sets {s=1} and {s=3} may be combined to yield the design {1,3}.

FIGURE 1 ABOUT HERE

In the random deletion method, the researcher elects to delete a fixed proportion of the data from the similarity matrix at random. Whereas Spence (1982) suggests that cyclic designs are the most efficient for handling incompleteness in large data sets, Spector and Rivizzigno (1982) have found that random designs performed as well or better than cyclic designs.[2] As random designs are easier to construct, it would seem useful to further explore the appropriateness of random versus cyclic designs, using empirical data rather than simulated data.

Another important issue in configuration recovery relates to the number of stimuli to be employed. There is a tendency to include a large number of stimuli in the respondent evaluation task with a view to increase the degrees of freedom. This tendency may be reinforced by Monté Carlo studies which report better configuration recovery for larger stimuli sets. For example, MacCallum and Cornelius (1977) found that, although stress values increased with increasing number of stimuli, configuration recovery in terms of metric determinancy improved with increase in the number of stimuli. Notwithstanding these results of the Monté Carlo studies, it was felt that in an empirical setting the task complexity would increase with an increase in the number of stimuli. Hence, considering the information overload effects, it was felt that configuration recovery would decrease with an increase in the number of stimuli. On the basis of the preceding discussion, the following hypotheses were examined:

H_1: Configuration recovery will be poorer with an increase in the proportion of proximity data deleted or treated as incomplete.

H_2: In deleting proximity data, random designs will perform as well as cyclic designs.

H_3: Configuration recovery will be poorer with an increase in the number of stimuli.

Data Collection

The subjects in this study were ninety management students at a large northeastern university. The stimuli consisted of familiar names of automobile brands. This selection of stimuli was guided by a consideration to avoid atypical applications of MDS. Automobiles have been employed in several MDS studies (e.g., Green, Maheshwari, and Rao 1969; Harshman, Green, Wind and Lundy 1982; Malhotra 1987; Summers and McKay 1976). The specific brands used were selected from the various car categories provided by Consumer Reports and a pre-test was conducted to ensure that respondents were familiar enough with the selected brands. As indicated earlier, it was felt that an increase in the number of stimuli might affect configuration recovery (Issac and Poor 1974; MacCallum and Cornelius 1977; Young 1970). Hence, three sets of automobile brand names consisting of, respectively, 25, 20, and 15 different brands were used.[3] These levels for the number of stimuli were selected as they seemed to be representative of the range of stimuli used in MDS research. Next, $n(n-1)/2$ pairs of brand were generated for each set. Subjects in the study were randomly assigned to one of the three stimuli conditions. The information obtained from the study participants included proximity judgments on all possible pairs of automobile brands on a seven point scale (1=very similar, 7=very dissimilar). The subjects were instructed to use their own criteria in judging the proximities. They were told to work at whatever pace that seemed most comfortable to them and reminded that for the scientific purposes of the study, it was extremely important that they concentrate and be consistent throughout all comparisons.

Analysis

To aid in our analysis, an experimental design involving three factors was set up as follows:

A. Number of stimuli: Between subjects factor.

   1. 15 brands of automobile
   2. 20 brands of automobile
   3. 25 brands of automobile

B. Method of data deletion (selecting judgmental pairs): Within subjects factor.

   1. Random
   2. Cyclical design

C. Percentage of the data treated as incomplete: within subjects factor.

   1. 20% of the total judgments
   2. 40% of the total judgments
   3. 60% of the total judgments

In random deletion, a fixed proportion of data was excluded at random for each subject. Thus, the similarity judgments randomly deleted could be different for different subjects in the same cell (number of stimuli and percentage of incomplete data). For the cyclical design condition, the specific cyclic sets employed were constructed according to the procedure outlined by Spence and Domoney (1974) and Spence (1982). The design yielded 2 (method of selecting judgmental pairs) x 3 (percentage of the data withheld from the total pair-wise judgments provided by the subjects) or 6 different matrices of proximity data for each subject in a particular stimuli condition. Since three different levels of stimuli were used and we had 30 subjects in each stimuli condition, a total of 540 different sets of incomplete proximity measures were available for analysis.

Data analysis was performed in two steps. First, the total proximity judgments obtained from each subject were independently analyzed via Takane, Young and de Leeuw's (1977) ALSCAL procedure. Three complementary approaches suggested in the psychometrics literature were employed to determine the appropriate dimensionality of MDS solutions (a) the elbow criterion of plotting the stress value against the dimensionality to form a polygon (Schiffman, Reynolds and Young 1981); (b) Spence and Graef's (1974) MSPACE procedure which compares the observed stress values with simulated stress values; and (c) other rules of thumb frequently used by applied psychometricians (e.g., Kruskal and Wish 1978, p. 52). Our analysis indicated that the data of subjects in 25 and 20 stimuli conditions could best be represented in a four dimensional configuration. However, the data for subjects in the 15 stimuli condition required only three dimensions for adequate representation. These dimensions were later used as the benchmark in which the 540 incomplete matrices were next analyzed.[4]

To examine configuration recovery under the different study conditions, the configurations derived using incomplete data were compared with the input proximities provided by each subject. Specifically, product moment correlations between the distances recovered by ALSCAL using incomplete data matrices and input distances in the form of proximity judgments were computed for each subject. Configuration recovery defined in this manner would most closely resemble the corresponding measure employed in Monté Carlo studies.[5] The use of interpoint distance correlations to examine the match between MDS configurations has been common in Marketing (e.g., Malhotra 1987; Moinpour, McCullough and MacLachlan 1976; Moore and Lehmann 1982; Summers and McKay 1976) as well as in Psychometric literature (e.g., Girard 1976; Graef and Spence 1979; Rabinowitz 1976; Spence 1982; Spence and Domoney 1974; Weeks and Bentler 1982; Young 1970). In reviewing the literature, Green (1975, p. 75) states that "recovery ability has generally been measured by the product moment correlation (or its square) between the interpoint distances of original versus recovered configurations". Yet, it should be noted that the recovery of distances has been assessed rather than the configuration itself. However, as Graef and Spence (1979, p. 62) point out, "in practical terms this makes little difference, since many previous Monté Carlo studies have shown that when the distances are well recovered, so is the configuration and vice versa." Stress was not employed as a recovery measure in these investigations as stress values would not be comparable across conditions with different percentage of missing data (MacCallum 1978).[6]

It is also important to note that the "recovery" measure used here is not the same measure used in the Monté Carlo literature. In Monté Carlo studies, the true distances in the subject's true configuration are known and it is possible to measure their recovery with either complete or incomplete data. However, since our study involves empirical data and therefore unknown true distances and configurations, the statistic utilized here does not measure recovery of a true solution but rather recovery of the input data at the individual level. Hence, in this investigation the true or base configuration is defined idiosyncratically for each individual.[7] To avoid any possible confusion, it is probably more appropriate to refer to our statistic as a measure of stability or robustness of MDS configurations in the face of incomplete data.

Keeping this caveat in mind, Table 1 presents mean correlation values under different data conditions. These correlations should be judged reasonable when compared to analogous Monté Carlo results with modest amount of error (MacCallum 1978; MacCallum and Cornelius 1977; Graef and Spence 1979). We observe from Table 1 that the correlation values decline with the increase in the proportion of data withheld from the proximity matrices. This decline is evident across the two methods of deleting proximity data <u>and</u> different numbers of stimuli. Furthermore, we do not notice substantial differences across different methods of data deletion. Both methods seem to be equally "efficient", with the differences being typically in the neighborhood of 0.02. To examine the statistical significance of these results, first the correlations were transformed using Fisher's Z transformation. An analysis of variance with one grouping factor and two trial factors repeated measures design was used. The grouping factor consisted of the number of stimuli, whereas the two trial factors consisted of the method of deletion (two levels) and the percentage of data deleted (three levels).

<u>TABLE 1 ABOUT HERE</u>

Only main effects for the number of stimuli ($F = 4.17$, d.f = 2) and the percentage of data deleted ($F = 428.11$, d.f = 2) were found to be significant at $\alpha = 0.05$. Of all the two way and three way interactions, only the method of deletion x percentage of deleted data interaction is significant ($F = 5.92$, d.f = 2). As expected, configuration recovery declined with an increase in the number of stimuli. Subsequent post-hoc tests revealed that the effect of incomplete data was significant at each level of the method of deletion. The method of deletion x percentage of incomplete data interaction is caused by higher recovery via cyclical design when 20% and 40% data are missing but higher recovery via random deletion when 60% data are missing. However, as pointed out earlier, the differences due to the method of deletion are quite small and for substantive purposes an applied researcher need not be overly concerned about them. Furthermore, if one adjusts the significance level for multiplicity of tests (e.g., by dividing α by the number of tests), the significance of these effects disappears. Thus, we can conclude that the preliminary study provides support for H_1, H_2, and H_3. To shed further light on hypotheses H_1 and H_2, and to examine the relationship between configuration recovery and two individual differences variables, a follow up study was conducted. To limit the complexity of the design, the number of stimuli was held constant in the second study.

SECOND STUDY

Background

Summers and MacKay (1976) are among the first authors in the marketing literature to have recognized the importance of devoting attention to "...a conceptualization of the human processes which may underlie direct similarity judgments" (p. 290). Some of the conceptual issues that they raise concerning the use of direct similarity judgments are of direct relevance to our study. For example, they stress that certain subjects may have difficulties in perceiving and using differences on more than three dimensions to arrive at an overall judgment of similarity. Instead of consciously weighing dissimilarities and similarities - as it is usually assumed in MDS studies - consumers may obtain overall similarity judgments by "...collapsing a large set of dimensions into a smaller set of more general dimensions before assessing similarities between stimuli... For others the same judgments may be the result of an unconscious process of comparing Gestalt impressions about the relevant stimuli" (Summers and MacKay 1976, p. 290).

This, along with the literature in cognitive psychology, suggests that people differing in terms of ability to integrate information and/or to form general, holistic impressions of incoming stimuli may differentially respond to proximity judgment tasks. There is theoretical and empirical evidence to suggest that cognitive integration and imagery are two individual variables which are salient in this respect.

Cognitive Integration

Cognitive integration refers to the degree of interrelatedness of elements within a particular cognitive domain (Schroder et al. 1967; Streufert and Streufert 1978). People who have a complex integrative structure are said to be integratively complex. Evidence shows that the integratively complex can function at higher levels of information processing (Schroder, Driver and Streufert 1967), use more rules and decision time (Driver and Mock 1975) and are more tolerant of inconsistency and imbalance than cognitively simple (e.g., Crano and Schroder 1964). They develop "general laws" that may be used to systematize a large and differentiated body of information. Thus, it may be expected that the integratively complex can form more integrated judgments which can be recovered even when partial or incomplete information is used for MDS analysis. It has also been observed that they are more accurate in making pair-wise similarity judgments (Henry 1980), a finding which is particularly relevant to our investigation. Hence, the following hypothesis was entertained.

H_4: Configuration recovery using incomplete data will be superior for integratively complex subjects than for integratively simple subjects.

Imagery

Conceding that the exact nature of imagery is under debate (Anderson 1978, 1979), the concept of imagery can be broadly defined as "a mental event involving visualization of a concept or relationship" (Lutz and Lutz 1978). The use of imagery is well documented in tasks where subjects are asked to compare pairs of objects along some dimensions when the objects are presented as words or pictures (for recent reviews see Kosslyn 1980; Richardson 1980). Mental imagery contributes to these comparisons, particularly when judgments are made along semantic dimensions.

Congruent with this is a series of investigations (e.g., Metzler and Shepard 1974) suggesting that the subjects mentally examine images in making same/different judgments. Shepard and his co-workers (Shepard 1975, 1978; Shepard and Podgorny 1978) have attempted to show that these mental images are able to substitute for actual perception. Shepard's experiments are very relevant here because they usually involve MDS analyses. In these studies, subjects were asked to judge the similarity between a broader variety of stimuli (e.g., colors, odors, familiar faces, musical sounds and names). Shepard found that the similarity data were indistinguishable between the two conditions in which the stimuli were physically presented or only imagined. Furthermore, the MDS analyses suggested that individuals "were performing very similar mental processes in the perceptual and imaginal conditions, and second that these processes operated on properties of the relevant objects even when those objects were not physically present" (Shepard 1978, p. 132).

There is also evidence that good visualizers (i.e. individuals with clear and vivid as opposed to vague and dim imagery), are more accurate in recalling pictures and (concrete) words (Marks 1973; McKelvie and Demers 1979), and in detecting picture differences (Berger and Gaunitz 1979 - see Marks' 1983 reinterpretation of their findings).

Multidimensional Scaling in a very real sense is based on the premise that people have mental maps of the stimulus set and that there is a definite place for each stimulus in relation to the remaining set. The various algorithms attempt to "capture" this map through questioning. It is reasonable to expect that subjects with vivid visual imagery would be more efficient in responding to questions about the relative proximity of objects in their mental map. They have picture memory and can quickly place objects in relation to each other. Hence, one would expect better configuration recovery for high visualizers when information about relationships among all the stimuli is <u>not</u> used in MDS analysis. Based on this evidence, it was suggested that:

H_5: Configuration recovery using incomplete data will be superior for high visualizers than low visualizers.

<u>Data Collection</u>

The subjects in this second study were 119 management students at a large southern university. The stimuli consisted of the 20 brands of automobiles used in the first investigation. The proximity judgments were obtained on the same seven point scale as used in the earlier study. Subjects were told to use their own criteria in judging the dissimilarities. They were told to work at whatever pace that seemed most comfortable and to concentrate and be consistent throughout all comparisons. Cognitive integration was measured using the Impression Formation Test[8] (Streufert and Driver 1967; Streufert and Schroder 1962), and visual imagery was assessed via Marks' (1973) VVIQ instrument.[9]

<u>Analysis</u>

In the first investigation, the effect of missing data could be examined at only three levels of 20%, 40%, and 60%, given the complexity of the three factor design. However, in the second investigation, as the number of stimuli was constant at 20, the effect of incomplete data was examined at six levels from 10% to 60% in steps of 10%. Again, both the cyclical design and the random method of selecting paired comparisons were retained. This yielded 6 (proportion of data deleted) x 2 (method of selecting pairs) or 12 proximity matrices for each subject. The plan of data analysis was similar to that of the first investigation. As before, configuration recovery under different conditions was examined by estimating product moment correlations between the distances recovered by ALSCAL using incomplete data matrices and input distances in the form of proximity judgments for each subject.

Results

The basic results of configuration recovery are shown in Table 2. We observe from Table 2 that the recovery degrades as the proportion of missing paired comparisons increases. The configuration recoveries across the random and cyclical designs for selecting pairs of similarity judgments appear to be close. The two studies do not differ markedly in their correlation patterns.

TABLE 2 ABOUT HERE

A two trial factors repeated measures analysis of variance was conducted to statistically examine the effects of the amount of data deleted, and the method of deletion. The correlations were appropriately transformed to Fisher's z values prior to analysis. The result indicated a significant effect for the amount of data deleted as well as for the two factor interaction. Given the significance of the interaction, the effect of each factor was next examined at each level of the other factor. These post-hoc tests revealed that the effect of incomplete data was significant for each level of the method of deletion. However, the effect of method of deletion was significant in only two of the six cases. For 30% missing data, the cyclical design yielded significantly ($\alpha = 0.05$) higher recovery than random deletion. For 60% missing data, the random method of deletion gave significantly ($\alpha = 0.05$) higher configuration recovery. It should be observed, however, that in a substantive sense these differences are small. If one adjusts the significance level for multiplicity of tests (e.g., by dividing α by the number of tests), the significance of these effects disappears. Hence, H_1 and H_2 are supported.[10]

The effect of individual variables was examined by correlating the configuration recovery correlations with cognitive integration and imagery. These results are presented in Table 3. It can be seen that the integratively complex subjects exhibit higher configuration recovery with incomplete data. The correlations range from 0.1909 to 0.3651 and are significant at $\alpha = 0.05$ in all cases, thus providing support for hypothesis H_4. The results for visual imagery are also contained in Table 3. As higher scores on VVIQ denote lower imagery, the negative sign of the corresponding correlations in Table 3 is in the expected direction. Moreover, the correlations for deletion via cyclic design are significant at $\alpha = 0.05$. For random deletion, the results are not strong, with only one correlation being significant at $\alpha = 0.05$, while others being significant at $\alpha = 0.10$. Hence, support for H_5 is not that strong.

TABLE 3 ABOUT HERE

The possible interaction effects of cognitive integration and imagery with the method of deletion and the proportion of incomplete data were also examined. For each individual differences variable, the subjects were divided into two groups based on a median split. A two grouping factors and two trial factors analysis of variance was then performed on the normalized correlations. The two grouping factors consisted of cognitive integration and imagery, whereas method of deletion and proportion of incomplete data served as the trial factor. None of the interaction effects were found to be statistically significant. The findings with respect to the main effects were consistent with the results reported earlier.

DISCUSSION AND IMPLICATIONS

The objective of our paper was to empirically examine the effect of incomplete data and method of deletion on configuration recovery in MDS and to explain the quality of configuration recovery in terms of the cognitive integration and imagery variables. Towards this, specific hypotheses were formulated and examined in the context of two empirical studies.

Results of the two studies were encouraging and provided support for all the hypotheses. Hypothesis H_1 with respect to incomplete data was strongly supported in both investigations. The deletion of data by either cyclic design or random method was found to adversely impact configuration recovery. In contrast, the main effect of the method of deletion was not found to be statistically significant in any of the investigations. However, the interaction between method of deletion and percentage of incomplete data was significant in both investigations. When examined at each level of the percentage of incomplete data, in a few instances the differences due to the method of deletion were found to be significant. There was a slight tendency for cyclic designs to yield better configuration recovery at lower levels of incomplete data and for the random method to perform better at higher levels of incomplete data. However, in a pragmatic sense these differences were very small, being of the order of 0.02. Hence, hypothesis H_2 was supported in a substantive sense. It appears that the performance of the random method of deletion of dissimilarity data is quite comparable to that of cyclic designs, at least within the range of incomplete data considered. These conclusions are quite similar to those arrived at by Spence and Domoney (1974) in their Monté Carlo study. As long as the selection task is truly random, the results are unlikely to differ markedly.[11]

The effect of number of stimuli was found to be significant ($\alpha = 0.05$) in the hypothesized direction supporting H3. This could possibly be due to at least two reasons. First, as reported by MacCallum and Cornelius (1977), with error present in the data it seems that proportionately greater amount of input data may be required to obtain the same level of recovery with larger number of stimuli. Second, in the empirical setting, with increase in the number of stimuli the respondent evaluation task becomes more complex and burdensome thereby decreasing the quality of responses and increasing the level of error in the data.

The second study supported our hypothesis H_4 with respect to cognitive integration. The quality of configuration recovery was better for subjects with superior cognitive integration skills. As such subjects form more interrelated judgments, it is reasonable to conjecture that they yield MDS configuration which are less affected by the removal of some of the comparisons made.

Hypothesis H_5 related to imagery was also supported, although only modestly so. It is generally agreed in the psychological literature that the facility in making similarity judgments is related to the format of internal representation of knowledge. The two major general formats of representation are propositional knowledge and imagery. Whereas propositional knowledge involves deeper conceptual levels, imagery has been suggested as a particularly "economical" way for solving many similarity judgmental tasks (Pipkin 1982).[12] Our findings may be compared with a series of studies by Ernest (1980) demonstrating the superiority of high imagers on the Closure Speed and Mutilated Words tests. These tests tap one's capacity to construct a whole picture or word from incomplete information. These studies suggest that high imagers may have an advantage when asked to make consistent, united judgments out of paired comparisons proximity judgments. This is probably due to the integrative quality of images. As explained by Kieras (1978), "the integrated quality of the image is due to its perceptual nature, such as a gestalt- like principle of figural unity. In contrast, semantic representations do not have such unitized properties and so are subject to partial loss and less reliable recall. Hence, the better performance is the direct result of images being well integrated" (p. 549).

Our investigation utilized student subjects. While this was deemed appropriate in our context, there is a need to examine this problem utilizing nonstudent samples. Also, products other than automobiles need to be investigated. Automobiles are a relatively complex product evaluated in terms of many salient attributes. MacCallum and Cornelius (1977) imply that better configuration recovery is obtained by simple stimuli. Hence, there is a need to examine this problem using simple stimuli such as toilet soap and toothpaste. Another limitation is that only two individual traits—cognitive integration and imagery were investigated in this paper. Several other cognitive differences have been suggested in the literature (Goldstein and Blackman 1978), and the effects of these on configuration recovery should also be investigated.

A possible extension of this inquiry is to empirically examine the ability of three-way scaling procedures to recover structure in the data. More specifically, the use of individual differences scaling algorithms (e.g., INDSCAL, ALSCAL) deserve attention. At the individual level, the configuration recovery may decline with increase in incomplete data. However, it is quite possible that good recovery may be obtained at the group or subgroup level using individual differences scaling (Carroll 1972).

Towards this, one may consider classifying respondent's apriori into segments (e.g., favorite brand, demographics, usage level). All respondents could be presented with a core set of stimuli (representing perhaps the stimuli of greatest interest). In addition, within each apriori segment, respondents could be provided with an idiosyncratic set drawn from the remaining pairs. These additional pairs would be selected in such a way as to insure a minimum replication of the non-core stimuli within each apriori segment. Data, pooled within each segment may later be scaled through an individual differences scaling procedure. Another logical extension of this exploration will be the use of a test-retest design with control groups to collect proximity data under different experimental conditions instead of the post-hoc data deletion approach employed by us.

In conclusion, the contributions of our paper to the literature on MDS and individual differences related to cognitive processes are at least fourfold. First, it was shown that contrary to earlier Monté Carlo studies the quality of MDS configuration recovery declines as the number of stimuli increases. This has important implications for applied MDS researchers who are often obliged to study large numbers of stimuli to fully represent the competitive environment of the brands under investigation. Second, random methods of data deletion appear to perform as well as cyclic designs. Third, as expected configuration recovery is negatively effected by the amount of missing data. Hence, researchers need to exercise caution when deciding how much data to collect. Fourth, our research tentatively suggests that the way respondents process data to form similarity judgments may have an impact on how much data can be deleted. More specifically, it was shown that MDS configurations obtained from respondents high in cognitive integration and imagery are less affected by the removal of some of the input data. This is the first MDS study reported in marketing literature which has empirically examined the role of individual differences in cognitive processes underlying similarity judgments. Much remains to be done. It is crucial that the various data deletion methods which have been proposed be submitted to further testing and comparisons. It is equally important that the psychological traits and processes involved in the formation of proximity judgments be identified and carefully studied. Our paper was a modest step in that direction.

Footnotes

1. Our paper is limited to paired comparisons. Alternative methods for reducing large data sets, including subjective grouping and various kinds of sorting procedures, are described in Rao and Katz (1971). Thompson (1983) has proposed partial orderings as yet another approach to reduce the number of judgments.

2. In this context, there is some evidence to suggest that large distances (in the input data) are more critical to satisfactory configuration recovery than small and medium distances and therefore should not be deleted (Graef and Spence 1979; Issac 1982). However, in applied marketing research, it is often difficult to determine apriori which distances are large.

3. The automobiles included in the 25 stimuli condition were VW Rabbit, Lincoln Continental, Ford Thunderbird, Chevrolet Impala, Toyota Corolla, Ford Pinto, Oldsmobile Cutlass, Mercedes 240D, Mercury Cougar, Ford Granada, Dodge Aspen, Plymouth Fury, Volvo 240 series, Chevrolet Chevette, Cadilac Eldorado, Datsun-210, Ford LTD, AMC Matador, Buick Skylark, AMC Gremlin, Chrysler Cordoba, Honda Accord, Oldsmobile Toranado, Ford Mustang II and Buick LeSabre. The first 15 automobiles were retained in the 15 stimuli condition while the first 20 comprised the 20 stimuli condition.

4. As the percentage of data withheld increased, the available degrees of freedom declined. In particular, with 60% data missing, the available degrees of freedom only marginally exceeded the minimum degrees of freedom required for estimation (Spector and Rivizzigno 1982; Young 1970). While this problem could have been mitigated by scaling the data in a lower dimensionality, such an alternative was rejected. Scaling in lower dimensionality would have resulted in poorer fits for all the respondents, and any differences in configuration recovery due to individual traits might have been lost. Furthermore, this would be inconsistent with our objective of evaluating the recovery of the complete data configuration with an incomplete proximity matrix. Hence, both statistical and substantive considerations pointed to dimensionalities selected for analyses. As brought out by Kruskal and Wish (1978, p. 48), "the decision about the dimensionality to use for a given set of data is as much a substantive as a statistical question".

5. Recovery was also examined by comparing the configurations obtained through the use of incomplete and complete data sets. Specifically, product moment correlations between the distances recovered by ALSCAL using full data and incomplete data matrices were computed. However, due to space limitations and lack of comparability with Monté Carlo studies, these results are not reported here.

6. Recovery could also be determined by canonically correlating configurations obtained from the full matrix and incomplete data matrices. Alternatively, the respondents could be presented with the various perceptual maps and asked to determine their similarity and correspondence with the map based upon complete data (Summers and MacKay 1976, 1977; Wilkes and Wilcox 1977).

7. Some attempts have been made in marketing, particularly in the literature on halo effects, to determine the true configuration. However, given the thrust of our paper, we do not present this literature.

8. The authors would like to acknowledge the assistance of Dr. Susan Streufert for scoring the Impression Formation test.

9. The reader is referred to the standard literature on cognitive style (e.g., Goldstein and Blackman 1978) and imagery (e.g., Sheehan, Ashton and White 1983; Scott et al. 1979) for a comprehensive and critical review of alternative measurement methods.

10. Tests were performed to compare the variability of product moment correlations across the data deletion methods. None of the differences were found to be significant at $\alpha = 0.05$

11. However, if the researcher is uncertain about the true randomness of his/her random design, preference for a cyclical design will be a prudent decision. Alternatively, the researcher could statistically test the randomness of the pairs deleted.

12. The fact that use of images improves recovery does <u>not</u> imply that the MDS configurations thus obtained are of "better quality" than those obtained where propositional knowledge is involved. Actually, quite the opposite might be true if the images used are not good "examplars" of the stimulus domain under consideration.

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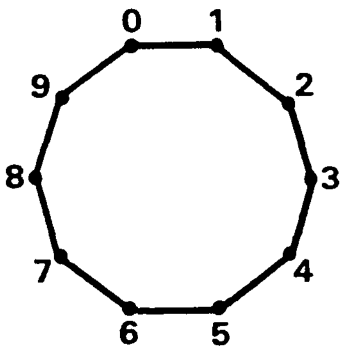
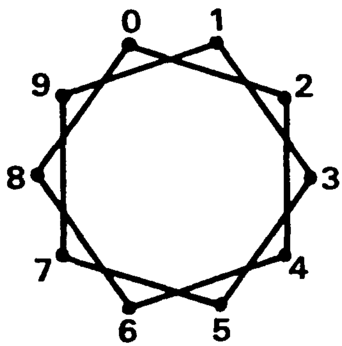
Figure 1
AN ILLUSTRATION OF A CYCLIC DESIGN



SET {S = 1}



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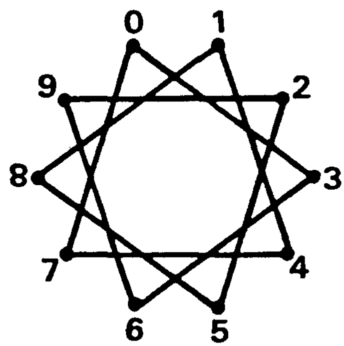

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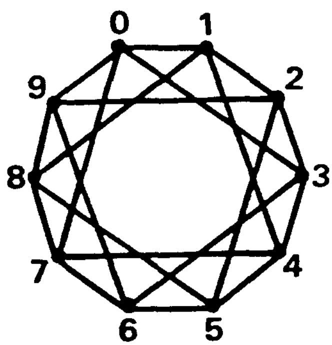

DESIGN {1,3}
FRACTION 20/45

TABLE 1

AVERAGE PEARSON PRODUCT MOMENT CORRELATIONS:
PRELIMINARY STUDY

Number of Stimuli	Deletion via Cyclic Design			Random Deletion		
	Percentage of Missing Data			Percentage of Missing Data		
	20	40	60	20	40	60
15	0.71	0.61	0.46	0.70	0.60	0.50
20	0.70	0.60	0.45	0.67	0.58	0.43
25	0.67	0.58	0.42	0.65	0.55	0.45

TABLE 2

AVERAGE PEARSON PRODUCT MOMENT CORRELATIONS
SECOND STUDY

Method of Deletion	Percentage of Missing Data					
	10	20	30	40	50	60
Cyclic Design	0.66	0.61	0.57	0.51	0.44	0.38
Random Deletion	0.66	0.61	0.55	0.50	0.45	0.40

TABLE 3

PEARSON PRODUCT MOMENT CORRELATIONS
FOR INDIVIDUAL CHARACTERISTICS

Individual Characteristics	Deletion via Cyclic Design						Random Deletion					
	Percentage of Missing Data						Percentage of Missing Data					
	10	20	30	40	50	60	10	20	30	40	50	60
Integration	0.31	0.27	0.30	0.34	0.19	0.23	0.35	0.36	0.33	0.37	0.25	0.28
Visual Imagery	−0.22	−0.20	−0.17	−0.20	−0.23	−0.16	−0.12[b]	−0.13[b]	−0.14[b]	−0.13[b]	−0.22	−0.14[b]

[a] All correlations except otherwise indicated, are significant at $\alpha = 0.05$

[b] Significant at $\alpha = 0.10$

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