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Analyzing Proximity Judgments In An Experimental Design

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by

Mary Lou Roberts
Assistant Professor of Marketing
University of Alaska
and
James R. Taylor
Associate Professor of Marketing
University of Michigan

FOR DISCUSSION PURPOSES ONLY

Abstract

This article reports the finding of a study designed to extend the use of proximity judgments to an experimental design. The analysis mode of Multidimensional Scaling (MDS) and Multivariate Analysis of Variance (MANOVA) was used to determine the causal relationships influencing respondents' perceptions of various types of coffee products.

Statement of the Problem

The analysis of proximity judgments by multidimensional scaling algorithms has aroused considerable interest in recent years because of their wide applicability to many types of marketing problems [3]. While studies employing this approach have been widely reported in business research and academic journals, few such studies involve the analysis of proximity judgments in the context of an experimental design. The problem lies in the lack of statistical procedures for analyzing treatment effects when the dependent measure involves more than one variable. The statistical procedure called Multivariate Analysis of Variance (MANOVA) was used in this research to analyze the proximity judgments [1, 2]. This statistical algorithm overcomes the problems associated with multiple dependent variables.

Methodology

It was decided to conduct an experiment in which two perceptual-producing variables could be manipulated. Various forms of coffee (ground, instant, freeze-dried, and so on) were selected as the stimulus objects because of their familiarity to subjects and previous research suggesting perceptual differences [6]. A 2 x 2 factorial design was employed. This design represents an instance in which two different sets of experimental treatments are crossed, or given in every combination.

In this study, there were four distinct sample groups, each group being given a particular combination of two kinds of treatments.

Treatment A consisted of a variation in the visual cue of size or shape of the coffee granules. Condition 1, the so-called large-granule condition had an appearance similar to freeze-dried coffee. Condition 2 was the smaller granule condition which had an appearance similar to regular instant coffee.

Treatment B involved a variation in the taste cue of the coffee. Condition 1 was a high-quality level (good) and condition 2 a low-quality level (bad). High- and low-quality variations were achieved by using expensive ground coffee prepared in twelve-cup perculators versus inexpensive private-brand instant coffee. Results of a pilot taste test demonstrated discrimination between the two quality levels.

The sample consisted of 461 subjects, all of whom were housewives recruited through voluntary organizations in the Ann Arbor, Michigan, locality. The subjects were randomly assigned to the four experimental groups. Thirty-three subjects were dropped from the analysis due to incomplete data forms and/or failure to understand the judging task.

The experimental procedure was divided into two stages. In stage 1, the subjects' perception of seven types of coffee products was measured. These coffee types were: preground in cans (ground), ground fresh in the supermarket (supermarket), low-caffeine ground, instant, low-caffeine instant, freeze-dried, and low-caffeine freeze-dried. Every pair of these coffee types was judged as to its degree of similarity on a seven-point scale ranging from not at all similar (1) to highly similar (7). A mean similarities score for all subjects was obtained for each pair. These mean scores were used to rank order the interpoint distances and this provided the input into the Guttman-Lingoes MINISSA-I algorithm [5].

In stage 2, a hypothetical new coffee product was introduced (treatment A). Half of the subjects received a written and pictorial message which portrayed the new coffee as an instant type (small-granule condition), while the remaining subjects received a message which portrayed the new coffee as a freeze-dried type (large-granule condition). Except for the manipulation of the visual cue of granule size, the messages were identical for both experimental conditions. The new coffee was presented as being the result of a new manufacturing process which produces the flavor and aroma of freshly perked coffee yet provides the convenience of instant coffee.

After the written presentation, a taste test was conducted (treatment B). Half of the subjects drank the high-quality coffee (condition 1), and half received the low-quality coffee (condition 2). After the taste test, data was again obtained on the similarity of the new coffee to the previous seven types of coffee.

Based on this experimental situation, three questions are of interest:

1. Are there systematic effects due to the visual cue of granule size alone (independent of the taste cue)?
2. Are there systematic effects due to variation in the taste cue alone (independent of the visual cue)?
3. Are there systematic effects due neither to visual cue alone nor to taste cue alone, but attributable only to the combination of a particular visual cue condition with a particular taste cue condition?

Results

Multidimensional Scaling Analysis

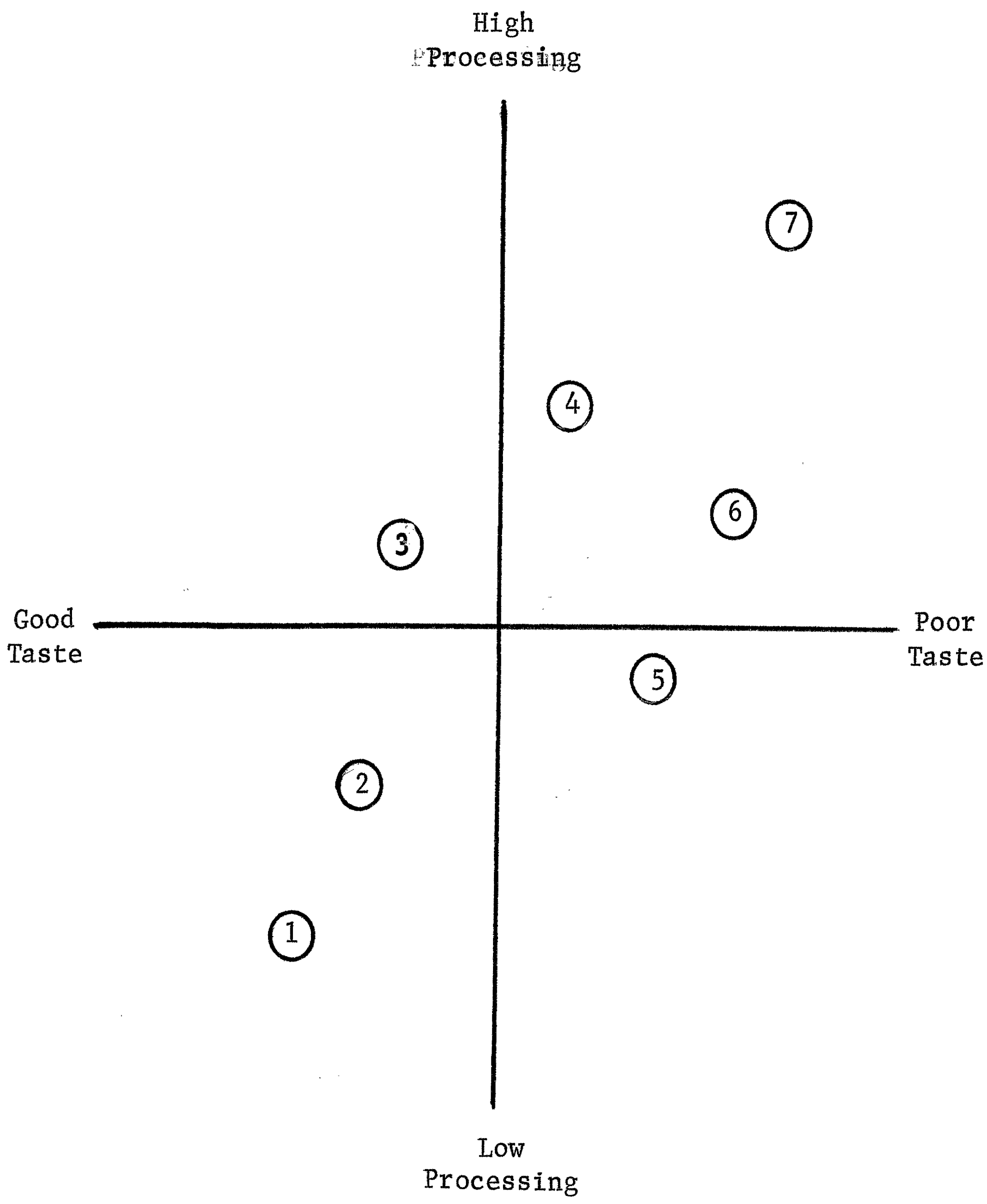
The stage 1 proximity judgments between the seven coffee types were analyzed with the Guttman-Lingoes MINISSA-I program. The coefficient of alienation was .178 in one dimension, .003 in two dimensions, and .001 in three dimensions. [2/] A two-dimensional representation was selected based on the level and decay rate of the coefficient of alienation. Figure 1 presents the two-dimensional perceptual space of the seven coffee types.

The subjects' rating of the seven coffee types on each of sixteen attributes was used to interpret the nature of the two-dimensional space. Only one of the sixteen attribute vectors fit the perceptual space. This attribute was pleasant taste (from not at all to very much). The horizontal dimension in Figure 1 represents this attribute.

The projection of the rating of the seven coffee types on this dimension has substantial face validity in that supermarket and ground are at the good-taste end while vending machine and low-caffeine instant are at the poor-taste end. After inspecting these projections on an orthogonal second dimension, it was hypothesized that this dimension could be the degree of product processing. At the low-processing end is supermarket and at the high-processing end is vending machine. The ranking of ground, low-caffeine ground, freeze-dried, low-caffeine instant, and instant might be viewed as an increasing degree of product processing. Alternatively, this dimension could be labeled a convenience dimension. Neither convenience nor degree of product processing was included in the original sixteen product attributes evaluated by the subjects.

Figure 1

PERCEPTUAL SPACE FOR SEVEN COFFEE TYPES



1 Supermarket
2 Ground
3 Freeze-Dried
4 Instant
5 Low-Caffeine Ground
6 Low-Caffeine Instant
7 Vending Machine

Following the experimental manipulation of the visual and taste cues, the subjects made similarity judgments pairing the new coffee to each of the seven coffee types. The new pairwise judgments were combined with the original proximity judgments to form an expanded proximity matrix. Four new coffee types, representing the four experimental groups, were included in the expanded proximity data set and this new proximity matrix was analyzed by the Guttman-Lingoes MINISSA-I program. The output of this program was used to determine the effect of the experimental manipulations by inspecting the locations of the new coffee types in the perceptual space. Note that this initial mode of analysis was extrastatistical.

Treatment A. Figure 2 shows the location of the two granule size conditions within the original stimulus configuration. Both the large- and small-granule conditions are located at the same location indicating that treatment A had no effect.

Treatment B. Figure 3 shows the location of the two taste conditions within the original stimulus configuration. It appears that there could be a treatment B effect in that the stimulus points are not located together.

The new coffee in both the good- and bad-taste conditions project at about the same location on the vertical dimension of degree of processing. Since both conditions represent the combined effect of the treatment A conditions, this result was expected. The projection of the new coffee in the good-taste condition, closer to the good-taste end of the horizontal dimension than the projection of the new coffee in the bad-taste condition, was also expected. Consequently, these results have substantial face validity.

Figure 2

PERCEPTUAL SPACE: VISUAL CUE EFFECT

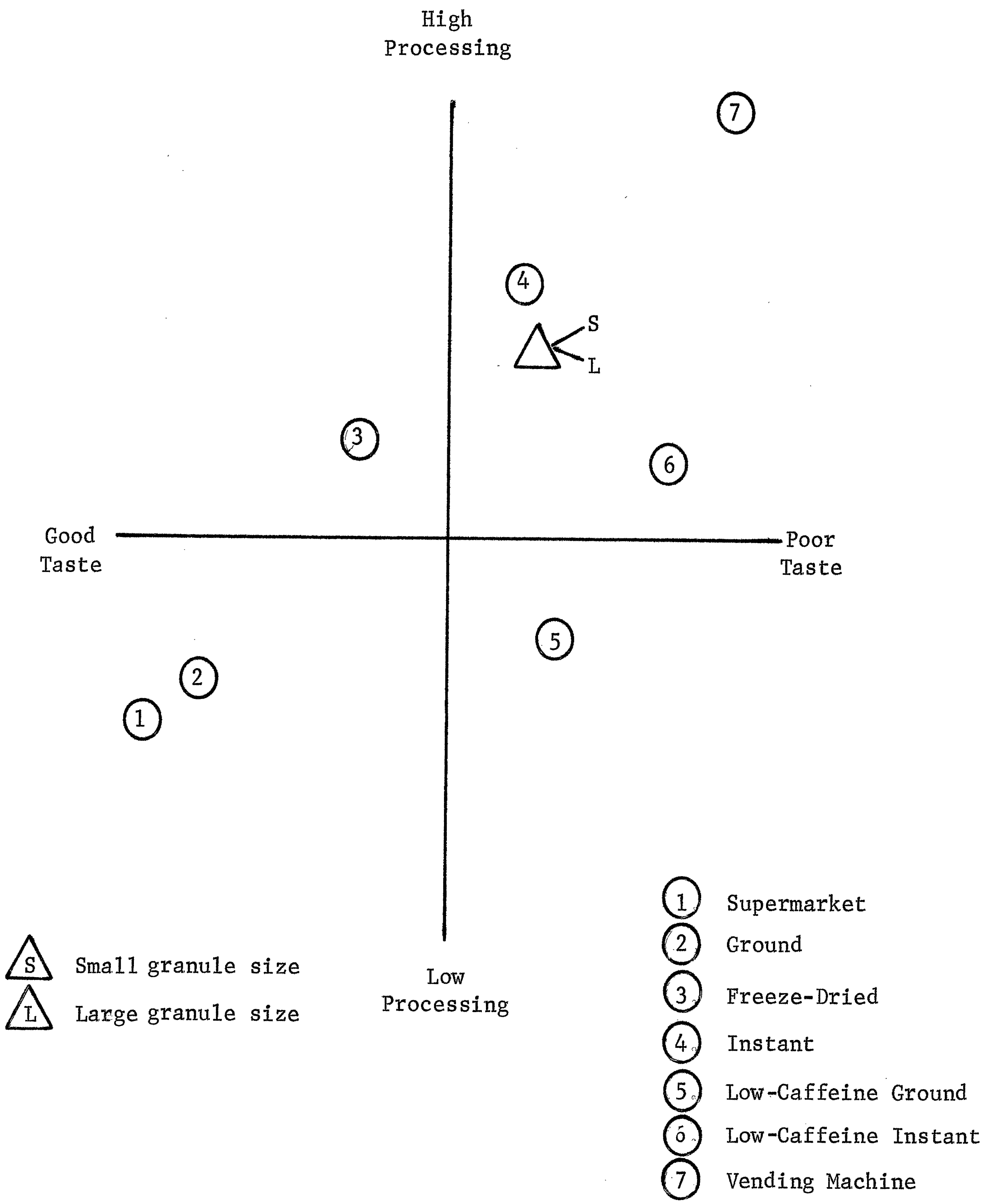
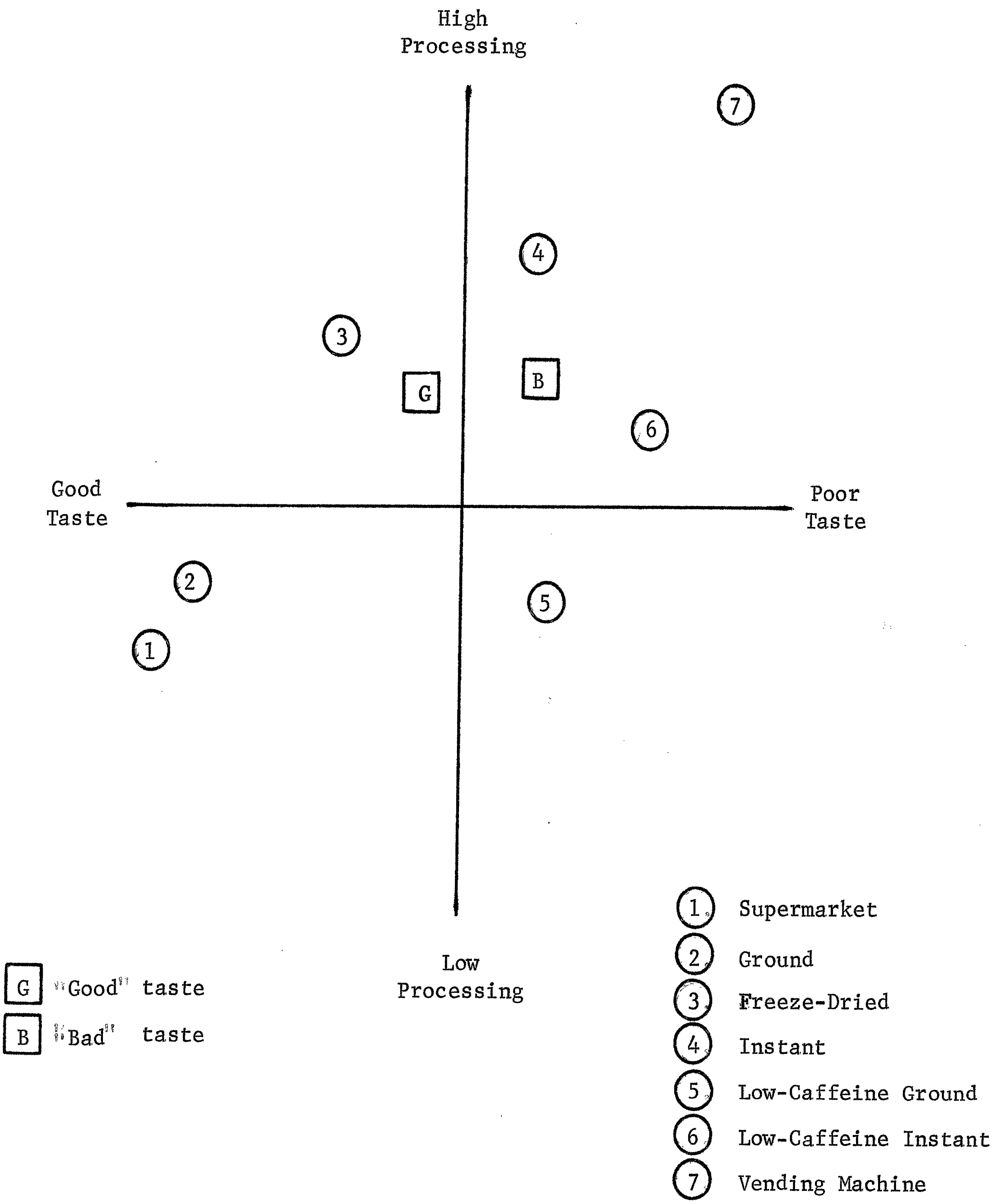


Figure 3

PERCEPTUAL SPACE: TASTE CUE EFFECT



Interaction Effect

Figure 4 shows the location of the new coffee for the four experimental groups in the perceptual space of the original stimulus configuration. These results present a more mixed picture than the previous findings. It appears that the two good coffee conditions project nearer the good-taste end of the horizontal dimension than the two bad coffee conditions. This was expected. In addition, the large-bad and small-bad coffee groups have similar projections on the degree of processing dimension. This finding was also expected.

The problem lies with the divergent positions of the large-good and small-good locations. The large-good location appears to project better taste and a substantially lower level of processing than the small-good new coffee condition. These findings appear to lead to an interaction conclusion. The low-quality taste cue substantially weakens or eliminates the visual cue effect while the high-quality taste cue strengthens the visual cue effect.

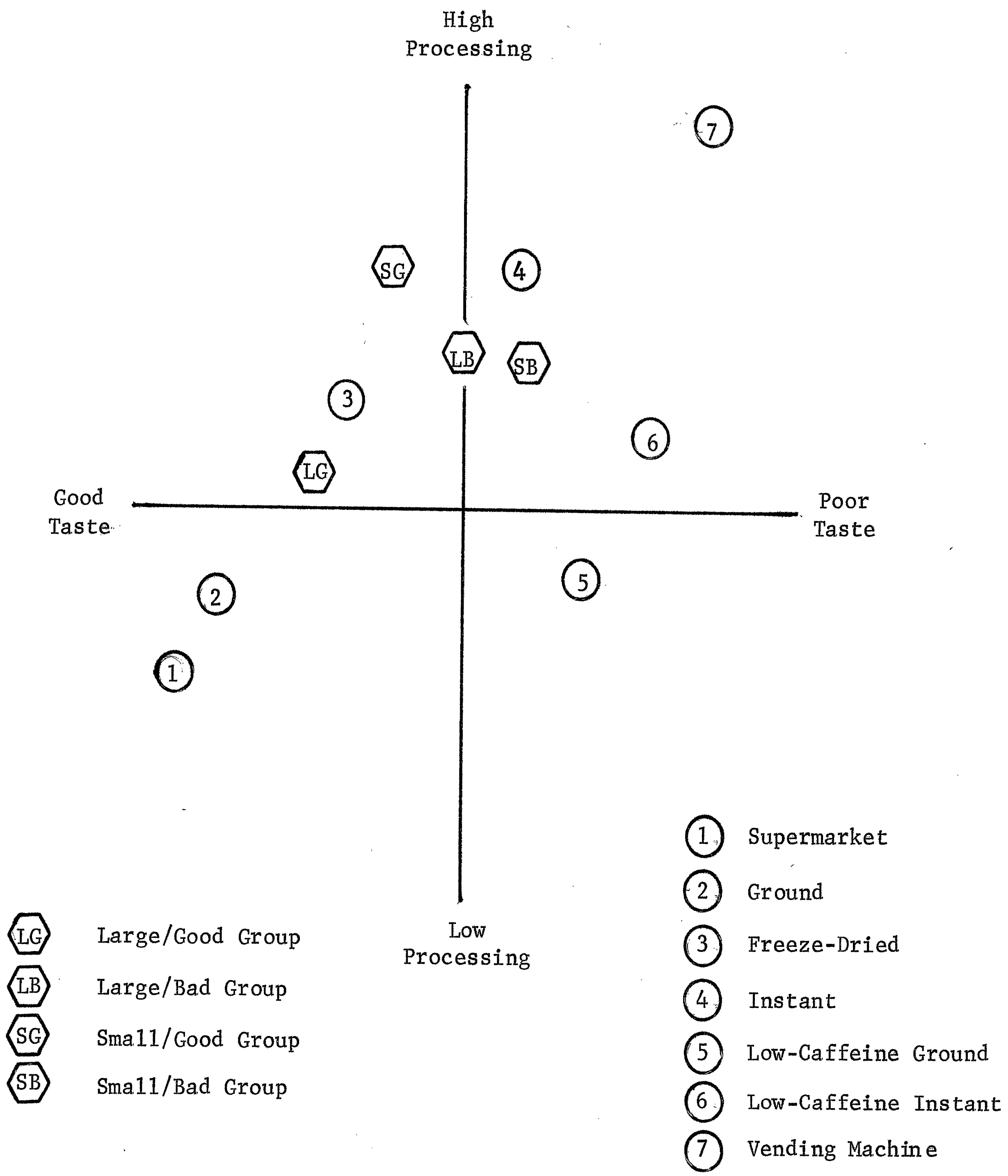
While the above data analysis is rather intuitive, the ability to distinguish random causes from treatment effects is a basic limitation of this mode of analysis. This type of problem has limited the use of proximity judgments in scientific research employing experimental designs. The Multivariate Analysis of Variance technique overcomes this limitation.

Multivariate Analysis of Variance (MANOVA)

Multiple dependent variables resulting from the pairwise comparisons in a manipulated object set constitute a problem when proximity data are used in an experimental design. In the current study, there were seven

Figure 4

PERCEPTUAL SPACE: INTERACTION



pairwise comparisons of the new coffee with the original seven coffee types. One analysis strategy could involve running seven separate analysis of variance using each of the seven dependent variables. However, the MANOVA program will do this univariate analysis of variance in addition to simultaneously analyzing the seven dependent variables. [3/] A general multiple regression approach to the analysis of variance is employed.

Table 1 presents the significance levels associated with the treatment effects for the seven dependent variables using a multivariate test of significance.

Treatment A. Table 1 indicates that the treatment A effect, after the effect of the B treatment was eliminated, was not statistically significant. This finding leads to the following assertion:

> There is apparently little or no effect of the visual cue alone on the perceived similarity of the new coffee to the original seven coffee types.

This conclusion is reflected in the identical plotting of the small- and large-granule conditions in Figure 2.

Treatment B. The treatment B effect, ignoring the treatment A effect, was statistically significant ($P < .001$). Based on this finding, the following assertion is made:

> The taste cue does seem to affect the perceived similarity of the new coffee when considered over the visual cue conditions.

This finding is consistent with the conclusion of the MINISSA programs based on an inspection of the multidimensional scaling results presented in Figure 3.

Table 1

SIGNIFICANCE LEVELS OF THE
TREATMENT EFFECTS

Effect	df	F-Value	p-Value
A	F (7;418)	0.54	ns
B	F (7;418)	4.23	.001
AxB	F (7;418)	1.80	.10
Grand Mean	F (7;418)	5318.29	.0001

AxB Effect. Table 1 indicates the AxB effect was statistically significant ($P < .10$). This implies that there are unique effects associated with various combinations of the treatments and leads to a qualification of the estimate one makes of the differences attributed to the two treatments. Consequently, the following assertion is made in regards to the AxB effect.

> There is apparently an interaction between the visual cue and taste cue, meaning that the magnitude and direction of the effects of the visual cue differ for different taste cue conditions.

This supports the previous extrastatistical analysis of the multi-dimensional scaling results presented in Figure 4.

Univariate Analysis

Tables 2 through 8 present the analysis of variance for each dependent variable. Given a significant multivariate effect, the uni-variate analysis can be used to better understand the nature of the effect.

The treatment B effect was basically caused by changes in the respondents' judgments about the similarity of the new coffee to super-market and ground. The data in Tables 2 and 3 indicate that the effect of treatment B was to influence the subjects so that they perceived the new coffee as closer to supermarket and ground in the good-taste condition than in the bad-taste condition.

The AxB effect was more pervasive than the treatment B effect. The data in Tables 4 through 7 indicate that interactions were observed when the new coffee was compared with freeze-dried, instant, low-caffeine

Table 2

ANALYSIS OF VARIANCE SUMMARY TABLE
NEW COFFEE - SUPERMARKET

Source	Sum of Squares	df	Mean Square	F-Value	p-Value
A	1.53	1	1.53	0.4611	ns
B	29.16	1	29.16	8.7887	.01
AxB	0.00	1	0.00	0.0004	ns
Grand Mean	3500.40	1	3500.40	1054.9241	.0001
Error	1406.90	424	3.3181		

Table 3

ANALYSIS OF VARIANCE SUMMARY TABLE
NEW COFFEE - GROUND

Source	Sum of Squares	df	Mean Square	F-Value	p-Value
A	1.49	1	1.49	0.4542	ns
B	67.39	1	67.39	20.4800	.0001
AxB	0.50	1	0.50	0.1525	ns
Grand Mean	3615.73	1	3615.73	1099.0596	.0001
Error	1394.89	424	3.2898		

Table 4

ANALYSIS OF VARIANCE SUMMARY TABLE
NEW COFFEE - FREEZE DRIED

Source	Sum of Squares	df	Mean Square	F-Value	p-Value
A	6.58	1	6.58	1.5745	ns
B	4.47	1	4.47	1.0692	ns
AxB	16.49	1	16.49	3.9479	.05
Grand Mean	8144.12	1	8144.12	1949.4314	.0001
Error	1771.34	424	4.1777		

Table 5

ANALYSIS OF VARIANCE SUMMARY TABLE
NEW COFFEE - INSTANT

Source	Sum of Squares	df	Mean Square	F-Value	p-Value
A	0.00	1	0.00	0.0003	ns
B	7.51	1	7.51	2.1309	ns
AxB	21.05	1	21.05	5.9731	.05
Grand Mean	7394.47	1	7394.47	2098.6157	.0001
Error	1493.96	424	3.5235		

Table 6

ANALYSIS OF VARIANCE SUMMARY TABLE
NEW COFFEE - LOW CAFFEINE GROUND

Source	Sum of Squares	df	Mean Square	F-Value	p-Value
A	3.05	1	3.05	1.1257	ns
B	7.44	1	7.44	2.7443	ns
AxB	19.34	1	19.34	7.1254	.01
Grand Mean	4599.08	1	4599.08	1695.522	.0001
Error	1150.09	424	2.7124		

Table 7

ANALYSIS OF VARIANCE SUMMARY TABLE
NEW COFFEE - LOW CAFFEINE INSTANT

Source	Sum of Squares	df	Mean Square	F-Value	p-Value
A	0.28	1	0.28	0.0862	ns
B	3.32	1	3.32	1.0240	ns
AxB	20.80	1	20.80	6.4167	.05
Grand Mean	5707.87	1	5707.87	1760.4417	.0001
Error	1374.73	424	3.2422		

Table 8

ANALYSIS OF VARIANCE SUMMARY TABLE
NEW COFFEE - VENDING MACHINE

Source	Sum of Squares	df	Mean Square	F-Value	p-Value
A	0.00	1	0.00	0.0009	ns
B	0.08	1	0.08	0.0167	ns
AxB	3.97	1	3.97	0.8449	ns
Grand Mean	4919.15	1	4919.15	1050.3149	.0001
Error	1985.80	424	4.6835		

ground, and low-caffeine instant. Figure 5 illustrates the nature of these interactions.

In comparing the similarity of the new coffee with freeze-dried, the size of the visual cue effect is dependent upon the taste cue condition, or vice versa. The main similarity score for the large-granule condition is significantly higher than the small-granule condition within the good-taste condition. Within the bad-taste condition, the difference in the mean similarity scores appears to be near zero.

In the comparison of instant and low-caffeine instant with the new coffee, the direction of the visual cue effect is dependent upon the taste cue condition. For both comparisons, the mean similarity score for the large-granule condition is significantly higher than the small-granule condition in the good-taste condition. This finding is similar to that of the freeze-dried - new coffee comparison. However, in the bad-taste condition, the direction of the mean scores is reversed for both comparisons.

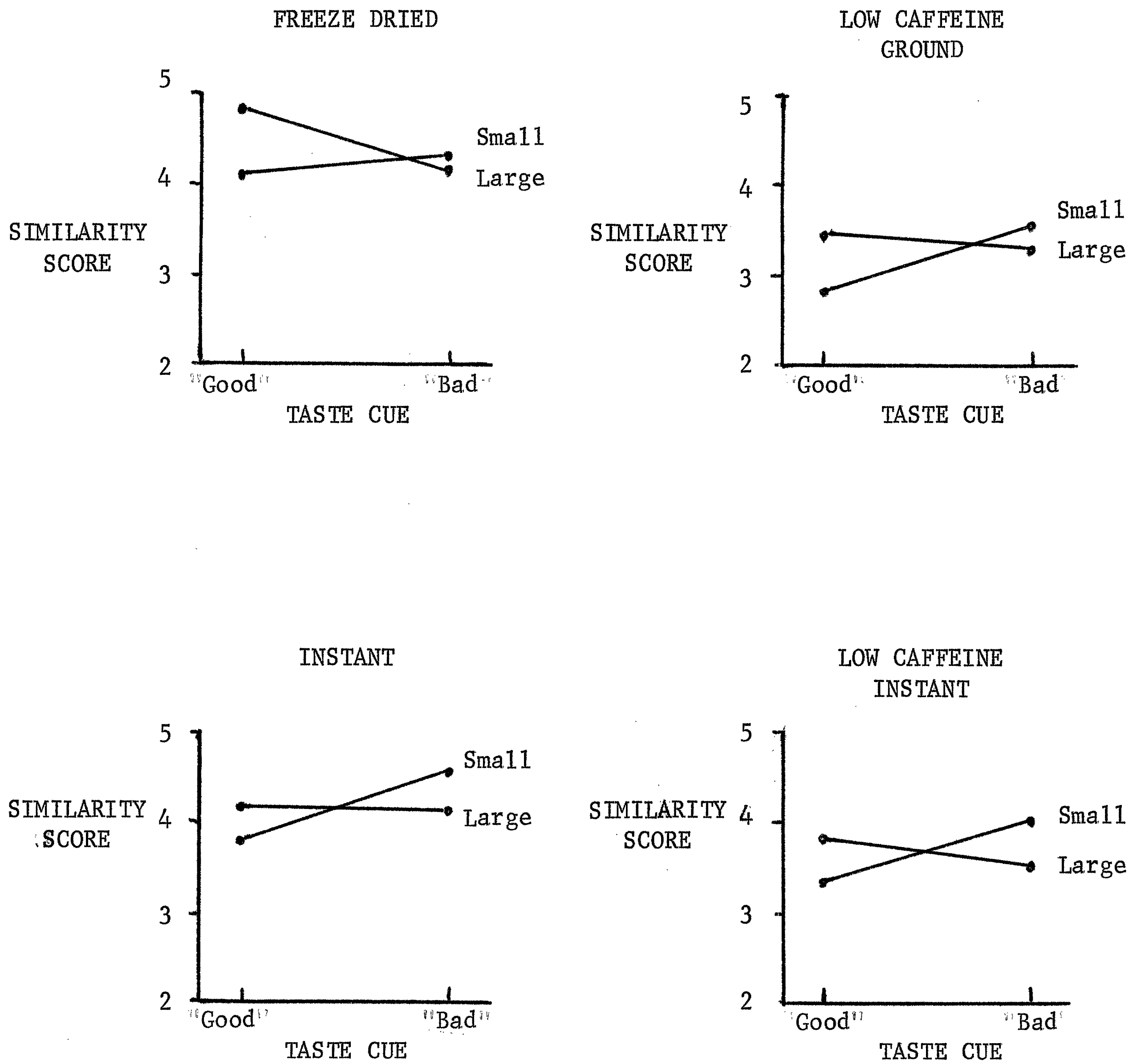
Both the direction and size of the visual cue effect is dependent upon the taste cue condition for the new coffee - low-caffeine ground comparison. The mean similarity score for the large-granule condition is significantly higher than the small granule condition in the good-taste condition, while the direction of the mean scores is reversed in the bad-taste condition. In addition, within the bad-taste cue condition the difference of the mean similarity scores appears smaller.

Discussion

The nonsignificant visual cue main effect was not expected. Since

Figure 5

INTERACTION BETWEEN "NEW" COFFEE TYPE
AND FOUR EXISTING COFFEE TYPES



the advertising strategy for many instant products emphasize granule size as a point of product differentiation (e.g., Maxim), it was anticipated that the respondents' perception of freeze-dried and instant coffee would be generalized to the new coffee through the common characteristic of granule size. We assumed this would be reflected in a significant visual cue main effect and in the new coffee being positioned near freeze-dried coffee in the large-granule condition and near instant in the small-granule condition. The finding that the new coffee positioned itself adjacent to instant coffee in the large condition (unexpected) and in the small condition (expected) suggests there are no systematic effects due to granule size alone. However, the process is more complex than this as demonstrated by the interaction between the visual cue and taste cue.

The significant taste cue main effect was anticipated. It was expected that the high-quality taste condition would influence the positioning of the new coffee in the proximity of ground and supermarket since the taste cue involved expensive ground coffee. In the low-quality taste condition, it was expected the new coffee would be near instant due to the inexpensive private-brand coffee used in this condition. In addition, it was anticipated that the main effect would correspond to a taste dimension in the stimulus configuration.

The MDS and MANOVA results generally confirm these expectations. The finding that the new coffee in the high-quality condition positioned itself near freeze-dried, rather than ground, illustrates the importance previous experience with instant-type coffee plays in formulating perceptions for the new coffee. If the respondent had relied entirely on the taste cue and the supporting message, which suggested the new coffee had the flavor and aroma of freshly ground perked coffee, the new coffee would have projected near ground coffee on the taste dimension. Actually, freeze-dried coffee projected nearer ground coffee than did the new coffee in the high-quality condition.

The problem caused by the public's tending to generalize past product experience which then influences pre- and post-trial perceptions of a new product is illustrated by the respondents' perceptions of low-caffeine instant and ground coffee (Figure 1). Previous research studies indicate that consumers' poor-taste perceptions of low-caffeine coffee are not entirely justified by the taste characteristics of contemporary low-caffeine products [4] . Apparently, perceptions based on initial lower-quality instant coffee products and the public's belief that caffeine extraction lowers the taste characteristics of coffee are generalized to new low-caffeine products and reformulated older products. Extensive advertising campaigns aimed at correcting this perceptual bias have obviously been very slow in changing these perceptions. Both low-caffeine ground and instant project near vending machine coffee at the poor-taste end of the taste dimension.

Because of a lack of direct empirical evidence or an adequate theoretical basis for anticipating the nature of an interaction, the AxB interaction effect was not expected.

While interactions always appear difficult to interpret, the situation seems even more complex when dealing with multiple dependent variables. Actually, the combined MDS-MANOVA analysis makes this task easier than expected. By comparing the MDS perceptual space (Figure 4) with the MANOVA univariate interactions (Figure 5), the relationship of each univariate interaction to the multivariate interaction becomes clearer. For each of the four coffee types in Figure 5, the rank order of the four experimental group similarity scores should reasonably correspond to the rank order of the interpoint distances between the respective coffee types and the location of the four new coffee locations in the perceptual space. An inspection of these rank orders, allowing for ties, reveals a reasonable correspondence.

The implication of the interaction effect is that the highly-advertised large-granule-size feature has the effect of increasing the perceived similarity of a new coffee product to ground and supermarket coffee given that the taste is as good as fresh-perked ground coffee. However, given a lower-quality taste experience, the visual cue has little effect and a large-granule size visual cue will not compensate for the lower quality level.

Summary and Conclusion

Proximity judgments have been used predominately in survey research where the association between variables can be evaluated but firm statements of causation are not possible. The purpose of this study was to extend the use of proximity judgments to an experimental design in such a way that causal relations could be studied. Of particular interest was the determination of the sensitivity and consistency of the respondents' perceptions to experimental manipulations. The feasibility of applying the MDS-MANOVA analysis mode to this problem was also investigated.

The results of the study were very encouraging. The MANOVA statistical findings support the extrastatistical analysis of the MDS results. The MDS-MANOVA analysis mode allows researchers to design experiments in which the effect of variable manipulation can be statistically determined in the context of a perceptual space. It is hoped that new insight can be gained through similar experiments in important areas such as product positioning-segmentation strategy and the effect of marketing communication on product perception.

Footnotes

1. Mary Lou Roberts is Assistant Professor of Marketing, University of Alaska. James R. Taylor is Associate Professor of Marketing, University of Michigan.

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2. The coefficient of alienation indicates how well the points plotted on the multidimensional map preserve the original rank order of the input data. It is a nonmatric loss function which explains the unaccounted for variance in terms of fit. A generally acceptable level of fit would be $K \leq .15$, and a $K \leq .05$ would be considered excellent.

3. The calculations were performed using the OSIRIS MANOVA program. OSIRIS is a computer software system developed at the Institute for Social Research, University of Michigan. The OSIRIS MANOVA program is an adaptation of the 1962 MANOVA program written by C.E. Hall and E.M. Cramer, then both at The George Washington University.

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Figures