

Block 20: Multidimensional scaling

(Activity solutions can be found at the end of the document.)

Multidimensional scaling allows the perceptions and preferences of consumers to be clearly represented in a spatial map. Perceived or psychological relationships among stimuli are represented as geometric relationships among points in a multidimensional space.

Learning Objectives

- discuss the basic concept and scope of multidimensional scaling (MDS) in market research and describe its various applications
- describe the steps involved in MDS of perception data, including formulating the problem, obtaining input data, selecting an MDS procedure, deciding on the number of dimensions, labelling the dimensions and interpreting the configuration and assessing reliability and validity
- explain the MDS scaling of preference data and distinguish between internal and external analysis of preferences
- explain correspondence analysis and discuss its advantages and disadvantages.

20.1 Multidimensional scaling

Statistics associated with multidimensional scaling

Multidimensional scaling (MDS) is a class of procedures for *representing perceptions and preferences* of participants spatially by means of a visual display.

Perceived or psychological relationships among stimuli are represented as *geometric relationships* among points in a multidimensional space. These geometric representations are often called *spatial maps*. The axes of the spatial map are assumed to denote the psychological bases or underlying dimensions which participants use to form perceptions and preferences for stimuli.

Statistics associated with MDS are the following.

Similarity judgements. Similarity judgements are ratings on all possible pairs of brands or other stimuli in terms of their similarity using a Likert-type scale.

Preference rankings. Preference rankings are rank orderings of the brands or other stimuli from the most preferred to the least preferred. They are normally obtained from the participants.

Stress. Stress is a lack-of-fit measure; higher values of stress indicate poorer fits.

R²R². R²R² is a squared correlation index which indicates the proportion of variance of the optimally-scaled data which can be accounted for by the MDS procedure. This is a goodness-of-fit measure.

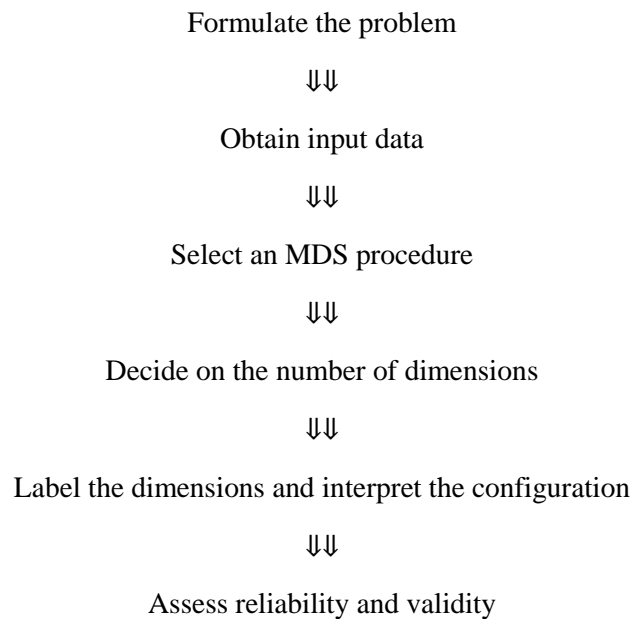
Spatial map. Perceived relationships among brands or other stimuli are represented as geometric relationships among points in a multidimensional space called a spatial map.

Coordinates. Coordinates indicate the positioning of a brand or a stimulus in a spatial map.

Unfolding. The representation of both brands and participants as points in the same space is referred to as unfolding.

Conducting MDS

The process to conduct multidimensional scaling is as follows:



Conducting multidimensional scaling

Specify the purpose for which the MDS results would be used. Select the brands or other stimuli to be included in the analysis. The number of brands or stimuli selected normally varies between 8 and 25. The choice of the number and specific brands or stimuli to be included should be based on the statement of the market research problem, theory and the judgement of the researcher.

[Figure 26.2 of the textbook](#) shows the different types of input data for MDS.

Perception data: direct approaches. In direct approaches to gathering perception data, the participants are asked to judge how similar or dissimilar the various brands or stimuli are, using their own criteria. These data are referred to as *similarity judgements*. The number of pairs to be evaluated is $n(n-1)/2$, where n is the number of stimuli.

Consider the following example where participants are asked for similarity judgements on all possible pairs of bottled beer brands:

	Very dissimilar						Very similar
Becks versus Budweiser	1	2	3	4	5	6	7
Budweiser versus Carlsberg	1	2	3	4	5	6	7
Carlsberg versus Corona	1	2	3	4	5	6	7
.
.

Bottle feels good to hold	–	–	–	–	–	–	–	Bottle does not feel good to hold
.
.
.
Has a strong smell of hops	–	–	–	–	–	–	–	No smell of hops

The direct approach has the following advantages and disadvantages.

- The researcher does not have to identify a set of salient attributes.
- The disadvantages are that the criteria are influenced by the brands or stimuli being evaluated.
- Furthermore, it may be difficult to label the dimensions of the spatial map.

The attribute-based approach has the following advantages and disadvantages.

- It is easy to identify participants with homogeneous perceptions.
- The participants can be clustered based on the attribute ratings.
- It is also easier to label the dimensions.
- A disadvantage is that the researcher must identify all the salient attributes, a difficult task.
- The spatial map obtained depends on the attributes identified.

It may be best to use both these approaches in a complementary way. Direct similarity judgements may be used for obtaining the spatial map and attribute ratings may be used as an aid to interpreting the dimensions of the perceptual map.

Preference data order the brands or stimuli in terms of participants' preference for some property. A common way in which such data are obtained is through *preference rankings*. Alternatively, participants may be required to make *paired comparisons* and indicate which brand in a pair they prefer. Another method is to obtain preference ratings for the various brands. The configuration derived from preference data may differ greatly from that obtained from similarity data. Two brands may be perceived as different in a similarity map yet similar in a preference map and vice versa.

Activity 20.1

For what purposes are MDS procedures used?

Activity 20.2

Identify two market research problems where MDS could be applied. Explain how you would apply MDS in these situations.

Activity 20.3

What is meant by a spatial map?

Activity 20.4

Describe the steps involved in conducting MDS.

Activity 20.5

Describe the direct and derived approaches to obtaining MDS input data.

Selecting a procedure and deciding the number of dimensions

Selection of a specific MDS procedure depends on:

- whether perception or preference data are being scaled or whether the analysis requires both kinds of data.
- the nature of the input data is also a determining factor:
 - non-metric MDS procedures assume that the input data are ordinal, but they result in metric output
 - metric MDS methods assume that input data are metric. Since the output is also metric, a stronger relationship between the output and input data is maintained and the metric (interval or ratio) qualities of the input data are preserved.
 - the metric and non-metric methods produce similar results.
- Another factor influencing the selection of a procedure is whether the MDS analysis will be conducted at the individual participant level or at an aggregate level.

In deciding the number of dimensions, the following should be taken into account.

- **A priori knowledge** - Theory or past research may suggest a particular number of dimensions.
- **Interpretability of the spatial map** - Generally, it is difficult to interpret configurations or maps derived in more than three dimensions.
- **Elbow criterion** - A plot of stress versus dimensionality should be examined. [Figure 26.3 of the textbook](#) shows an example of a plot of stress versus dimensionality.
- **Ease of use** - It is generally easier to work with two-dimensional maps or configurations than with those involving more dimensions.
- **Statistical approaches** - For the sophisticated user, statistical approaches are also available for determining the dimensionality.

Activity 20.6

What factors influence the choice of an MDS procedure?

Activity 20.7

What guidelines are used for deciding on the number of dimensions in which to obtain an MDS solution?

Label the dimensions and interpret the configuration

Even if direct similarity judgements are obtained, ratings of the brands on researcher-supplied attributes may still be collected.

Using statistical methods, such as regression analysis, these attribute vectors may be fitted in the spatial map. After providing direct similarity or preference data, the participants may be asked to

indicate the criteria they used in making their evaluations. If possible, the participants can be shown their spatial maps and asked to label the dimensions by inspecting the configurations.

If objective characteristics of the brands are available (for example, horsepower or kilometres per litre for cars), these could be used as an aid in interpreting the subjective dimensions of the spatial maps.

[Figure 26.4 of the textbook](#) of the textbook shows a spatial map for the bottled beer brands example using a two-dimensional solution.

Assess reliability and validity

The index of fit, or R^2 , is a squared correlation index which indicates the *proportion of variance of the optimally scaled data which can be accounted for by the MDS procedure*. Values of 0.60 or better are considered acceptable.

Stress values are also indicative of the quality of MDS solutions. While R^2 is a measure of goodness-of-fit, stress measures badness-of-fit, or the *proportion of variance of the optimally scaled data which is not accounted for by the MDS model*. Stress values of less than 10% are considered acceptable.

If an aggregate-level analysis has been done, the original data should be split into two or more parts. MDS analysis should be conducted separately on each part and the results compared.

Stimuli can be selectively eliminated from the input data and the solutions determined for the remaining stimuli. A random error term could be added to the input data. The resulting data are subjected to MDS analysis and the solutions compared. The input data could be collected at two different points in time and the test-retest reliability determined.

[Figure 26.6](#) of the textbook assesses the stability of the solution by deleting one brand.

It is assumed that the similarity of stimulus A to B is the same as the similarity of stimulus B to A. MDS assumes that the distance (similarity) between two stimuli is some function of their partial similarities on each of several perceptual dimensions. When a spatial map is obtained, it is assumed that inter-point distances are ratio-scaled and that the axes of the map are multidimensional interval-scaled. A limitation of MDS is that dimension interpretation relating physical changes in brands or stimuli to changes in the perceptual map is difficult at best.

Activity 20.8

Describe the ways in which the reliability and validity of MDS solutions can be assessed.

Scaling preference data and correspondence analysis

In internal analysis of preferences, a spatial map representing both brands or stimuli and participant points or vectors is derived solely from the preference data. In external analysis of preferences, the ideal points or vectors based on preference data are fitted in a spatial map derived from perception (for example, similarities) data. The representation of both brands and participants as points in the same space, by using internal or external analysis, is referred to as *unfolding*. External analysis is preferred in most situations.

Correspondence analysis is an MDS technique for scaling qualitative data in market research. The input data are in the form of a contingency table, indicating a qualitative association between the rows and columns. Correspondence analysis scales the rows and columns in corresponding units so that each can be displayed graphically in the same low-dimensional space. These spatial maps provide insights into (i) similarities and differences within the rows with respect to a given column category,

- (ii) similarities and differences within the column categories with respect to a given row category, and
- (iii) relationship among the rows and columns.

The advantage of correspondence analysis, as compared to other multidimensional scaling techniques, is that it *reduces the data collection demands imposed on the participants*, since only binary or categorical data are obtained. The disadvantage is that between-set (i.e. between column and row) distances cannot be meaningfully interpreted. Correspondence analysis is an exploratory data analysis technique that is *not* suitable for hypothesis testing.

If the attribute-based approaches are used to obtain input data, spatial maps can also be obtained by using factor analysis or discriminant analysis. By factor analysing the data, one could derive for each participant, nn factor scores for each brand. By plotting brand scores on the factors, a spatial map could be obtained for each participant. The dimensions would be labelled by examining the factor loadings, which are estimates of the correlations between attribute ratings and underlying factors.

To develop spatial maps by means of discriminant analysis, the dependent variable is the brand rated and the independent or predictor variables are the attribute ratings. A spatial map can be obtained by plotting the discriminant scores for the brands. The dimensions can be labelled by examining the discriminant weights, or the weightings of attributes which make up a discriminant function or dimension.

Activity 20.9

What is the difference between internal and external analysis of preference data?

Discussion forum and activities

To access the solutions to these questions and case study, click [here](#) to access the printable Word document or click [here](#) to go to LSE's Elearning resources.

Activity 1

Identify two market research problems where MDS could be applied. Explain how you would use the technique in these situations.

Activity 2

A participant's ratings of nine luxury car brands on four dimensions are shown. Each brand was evaluated on each dimension (prestige, performance, luxury and value) on a seven-point scale with 1 = poor and 7 = excellent. Develop an MDS plot in two dimensions. Explain the plot.

Brand	Prestige	Performance	Luxury	Value
Ferrari	5	7	5	7
Jaguar	5	6	5	7
BMW	5	7	6	5
Mercedes	6	6	6	6

Brand	Prestige	Performance	Luxury	Value
Audi	5	5	6	5
Lexus	6	6	5	5
Porsche	5	6	5	4
Bentley	7	4	7	3
Rolls Royce	7	4	7	1

Learning outcomes checklist

Use this to assess your own understanding of the chapter. You can always go back and amend the checklist when it comes to revision!

- Discuss the basic concept and scope of multidimensional scaling (MDS) in market research and describe its various applications
- Describe the steps involved in MDS of perception data, including formulating the problem, obtaining input data, selecting an MDS procedure, deciding on the number of dimensions, labelling the dimensions and interpreting the configuration and assessing reliability and validity
- Explain the MDS scaling of preference data and distinguish between internal and external analysis of preferences
- Explain correspondence analysis and discuss its advantages and disadvantages.

Solution to Activity 20.1

Multidimensional scaling (MDS) procedures are generally used for obtaining spatial representations of participants' perceptions and preferences through the application of spatial maps.

Solution to Activity 20.2

New product development. Gaps in a spatial map indicate potential opportunities for positioning new products. MDS can be used to evaluate new product concepts and existing brands on a test basis to determine how consumers perceive the new concepts. The proportion of preferences for each new product is one indicator of its success.

Assessing advertising effectiveness. Spatial maps can be used to determine whether advertising has been successful in achieving the desired brand positioning.

Solution to Activity 20.3

A spatial map is a geometric representation of perceptions and preferences of the participants. Here the perceived or psychological relationship among stimuli is described in the geometric relationship among points in a multidimensional space. The axes denote the psychological basis or underlying dimensions used by the participants to form perceptions and preferences for stimuli.

Solution to Activity 20.4

The following steps are involved in MDS.

1. *Formulating the problem.* The brands or stimuli which are to be included have to be specified along with the purposes for which the MDS results would be used.
2. *Obtaining input data.* The data obtained from the participants can be related to perceptions or preferences. Perception data could be obtained by derived or direct approaches. Preference data is obtained through preference rankings.
3. *Selecting an MDS procedure.* This is dependent on the nature (metric or non-metric) of the input data, whether perceptions and/or preferences are being scaled, and whether the analysis will be conducted at the aggregate or individual level. MDS procedures may be metric or non-metric.
4. *Deciding on the number of dimensions.* A compromise has to be made between the smallest number of dimensions needed for the best fit of input data into the spatial map and the number required to improve the fit. This decision should be based on theory, interpretability, the elbow criterion, ease of use and proficiency of the researcher.
5. *Labelling the dimensions and interpreting the configuration.* Once a spatial map is developed in a given dimensionality, the dimensions need to be labelled and the configuration interpreted. This requires subjective judgement on the part of the researcher and several guidelines are available for this purpose.
6. *Assessing reliability and validity.* The input data and the MDS solutions are generally subject to substantial random variability. Therefore, it is necessary to check the reliability and validity of the MDS solutions. This may be done by:
 - examination of index of fit or R²R²
 - evaluating stress values
 - comparing MDS solutions obtained through the addition of random error in the data.

Solution to Activity 20.5

In the direct approach (preferred for perception data), the participants are asked to directly judge the level of similarity (or dissimilarity) between the various brands or stimuli, using their own criteria. The participants may be asked to rate all possible pairs of brands or stimuli in terms of their similarity using a Likert-type scale. The participants could also be asked to rank-order all the possible pairs from most similar to least similar. Yet another method requires the participant to rank-order the brands in terms of their similarity to an anchor brand, where each brand in turn serves as an anchor. In the derived approach, the participants rate the brands or stimuli on the identified attributes. Next, a similarity measure (such as Euclidean distance) is derived for each pair of brands.

Solution to Activity 20.6

The choice of MDS procedure is influenced by:

- Type of data (preference or perception or both)
- Nature of input data (ordinal or metric)
- Whether the MDS analysis will be conducted at the individual participant level or at an aggregate level.

Solution to Activity 20.7

The general guidelines are as follows.

- The number of dimensions may be decided on the basis of past research or theory.
- The ability to interpret the spatial map decreases if it is constructed in more than three dimensions.
- It may be decided on the basis of the elbow criterion. The point at which a sharp bend occurs in a plot of stress versus dimensionality is regarded as the optimum number of dimensions.
- Ease of use should be kept in mind. Working with maps or configurations having more than two dimensions is difficult.
- If the researcher is proficient enough then the researcher can use statistical approaches for determining the dimensionality.

Solution to Activity 20.8

The reliability and validity of MDS solutions can be tested according to the following guidelines.

- Higher values (0.6 or better) of the index of fit or R^2 indicate how well the MDS model fits the input data. Therefore, an examination of this quantity serves as a good check.
- Stress values (the lower the better) can also serve as an indicator of good MDS solutions. Of course, their values depend on the type of MDS procedure and the data being analysed.
- In the case of aggregate level analysis, the original data should be split in two or more ways. MDS analysis should be conducted separately on each part and the results can be compared.
- Stimuli could be selectively eliminated from the input data and the solutions determined for the remaining stimuli.

- A random error term could be added to the input data. The resulting data is subjected to MDS analysis and the solutions compared.
- The input data could be collected at two different points in time and the test–retest reliability is determined.

Solution to Activity 20.9

The main distinction between them is that in internal analysis, both brand (or stimuli) and participant points (or vectors) can be represented in the same spatial map on the basis of the preference data only. However, in the external analysis the ideal points (or vectors) based on preference data are fitted in a spatial map derived from perception data. Therefore, both perception and preference data have to be obtained from the participants.

The external analysis is generally preferred in most cases, owing to computational ease and reliability.

Solutions to Activities on the block's topics

Activity 1:

Some possible examples in which MDS can be used are the following.

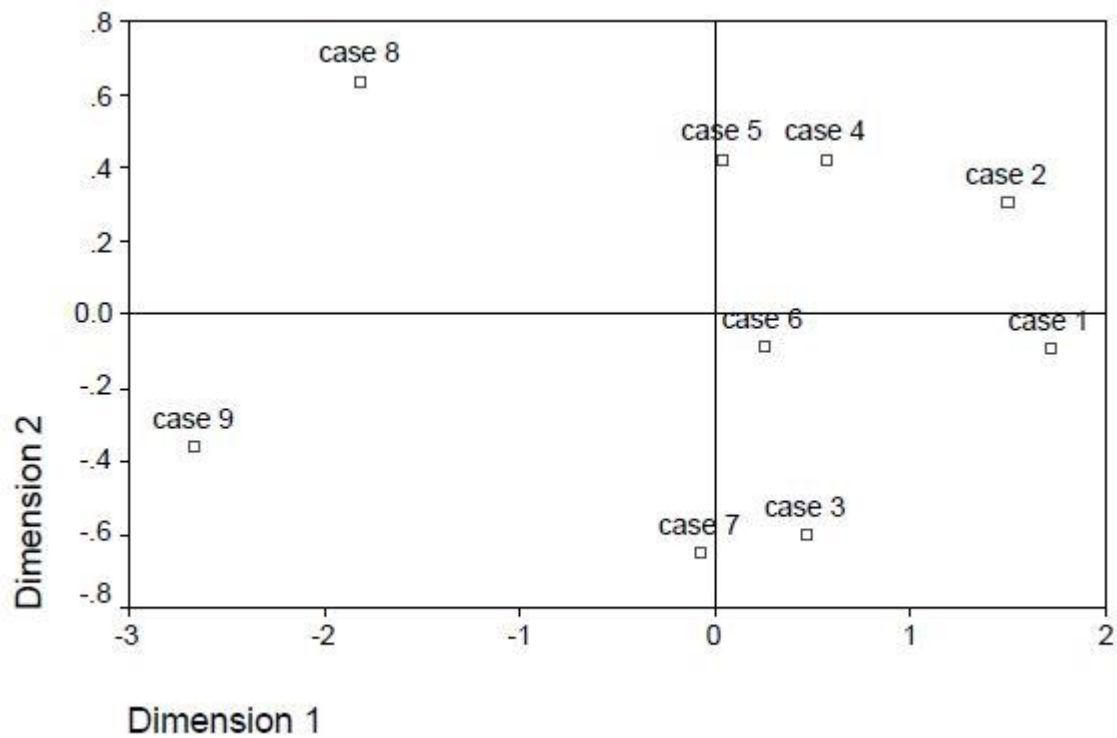
- *Image measurement* - The firm can compare its perceptions of its own image with the way the customers or non-customers perceive it.
- *Market segmentation* - This refers to the identification of groups of consumers with relatively homogeneous perceptions.
- *New product development* - A study of the gaps in a spatial map may reveal potential opportunities for positioning new products.
- *Assessing advertising effectiveness* - Through the spatial maps one can determine whether advertising has been successful in achieving the desired brand positioning.

Activity 2:

Define the following:

- Case 1: Lexus
- Case 2: Jaguar
- Case 3: BMW
- Case 4: Mercedes
- Case 5: Ferrari
- Case 6: Audi
- Case 7: Porsche
- Case 8: Bentley
- Case 9: Rolls Royce

The derived stimulus configuration using the Euclidean distance model is:



Based on the positioning of the cars, Dimension 1 may be interpreted as prestige, with prestige increasing from right to left. Therefore, Rolls Royce, as the most prestigious car, has the highest positioning on this dimension and Lexus the lowest. Dimension 2 may be interpreted as performance, with performance increasing from top to bottom. Therefore, Porsche has the highest performance and Bentley the lowest. Bentley has the second highest prestige.