INDSCAL

SPECIAL PROJECT 1987

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USE OF INDSCAL IN PRODUCT DESIGN

SEMINAR PROJECT

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APPROVAL SHEET

This seminar project, titled 'Use of INDSCAL for product design' is approved in partial fulfillment of the requirements for the Master of Design degree in Industrial Design.

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Project Guide

INTRODUCTION

Product design is a process of finding optimal solutions to a defined set of problems in a given product or system, being mostly concerned with the aspects of users - product relationships like ease of assembly, ease of maintenance, effective understanding of the product, visual aesthetic and ease of use, of the product.

The product has in it various attributes like shape, colour, size, weight, cost, value etc. that affect a buyer's decisions. To understand the effects of these attributes in already available products or in an conceptualised product, several evaluation methods are adopted by the designer. Some of them are paired comparision, cluster- analysis, factor analysis, bi-polar matrix and lately multi-dimensional scaling. INDSCAL is one of the techniques of MDS, performed with the help of a computer programme.

THE DESIGN PROCESS

The design process generally consists of :

1. The Brief
2. Data collection - Survey-Product, user and its environ.
3. Analysis -
   - Functional
   - Structural
   - Ergonomic
4. Problem identification
5. Design brief
6. Concepts
7. Final Design solution

THE ANALYSIS

Analysis is an important phase of the design process, as it enables the designer to identify the factors that affect the design decisions.

- As designers we are primarily concerned with the user and his needs.
- The aim of analysis is to :
  - understand the user's perception of the different product attributes.
  - understand the criteria for judgement
  - understand how consumers are related through differences or commonalities.
- These differences in perception are significant to the product structure.

- Every user would have his own subjective opinion on the various attributes of the product.
- Analysis of this variance is vital for design.

To consider two examples :

To design monetory coins, it is important to understand the features by which the different coins are differentiated. The attempt would be to obtain maximum dissimularity between the coins.

As regards a bath soap, it is necessary to understand how the user perceives different features of a soap like - fragrance, size, price, colour etc. From this we can understand what priorities are given to what attributes and our design can be matched to meet these perceptions of the user.

The designed product should be able to satisfy an intended segment of users. The analysis of the product may be aimed at evaluating an existing product, or, to survey a product area to evolve a suitable product, or even to manipulate a product towards another market segment.

As mentioned, there would be many attributes in a product and each user would have his own subjective opinion towards these attributes.

EVALUATION METHODS

The attributes and their opinions can be evaluated by various methods. Earlier methods, and still used for different reasons, were paired comparison, cluster analysis, factor analysis and bi-polar matrix ~~are~~ among those commonly used.

These methods gave a rank order co-relation between the various attributes. But the main drawbacks were that these methods required many subjects and only few stimuli could be evaluated, and also it had only a two-dimensional capability. That is how the need arose for a multi-dimensional scaling technique.

MDS

Multi-dimensional scaling or MDS was developed at Bell laboratories in the early 1960's. This technique was mainly used for the design of Bell's telephones. This technique again had its limitations, that the number of subjects had to be greater than ten and the number of stimuli had to be less than six. Also the procedure was rather time consuming.

Out of these drawbacks, a new system, INDSCAL - for Individual Differences Scaling was evolved. INDSCAL could conduct the study on small groups of 3 to 5 subjects and the number of stimuli could be ten to fifteen.

What is MDS

A survey is conducted to evaluate ten samples in a product category. Now, how similarly did the public view these products. What identifiable features can we discern in the varying evaluations of the samples that can help us understand what led the individual users to their decisions. Multidimensional scaling can help answer these questions.

The Basic concepts of MDS

Given a map of several cities in a country, it is not difficult to construct a table of distances between these cities. But where, the reverse problem is given, to produce a map from a table of dimensions, it is rather difficult, though geometrically it can be done. In effect MDS is a method of solving this reverse problem.

Multidimentional scaling refers to a class of techniques considering proximities among any kind of objects as input. A proximity is a number which indicates how similar or how different two objects are, or are perceived to be. The main output is a spatial representation consisting of a geometric configuration of points, as on a map. Each point in the confirguration corresponds to one of the objects. This configuration reflects the hidden structure in the data. By reflecting the data structure, it is meant that the larger the dissimilarity or smaller the similarity, between the two objects, as shown by their proximity value, the further apart they should be in the spatial map.

How MDS helps in Product Design

MDS provides information on :

- various product attributes that people use to distinguish one product from another.
- relative importance of attributes in making a distinction between products.
- relative importance of attributes in determining preferences.
- Differences of consumers in perception and preference- this would identify homogenous user groups.

Disadvantages of MDS

- Ratings from different subjects had to be averaged, before being fed into the computer.
- Only a 2-D solution is displayed
- Axes of the plot had to be rotated, discerningly, to interpret output from the computer.

- This tells only about the space for the average subject.
- No information on variations in perception is given.

INDSCAL

INDSCAL was developed to overcome the said problems. It is essentially same as MDS, but additionally :

- relates the spaces from different subjects, while permitting large differences.
- Individual subject space is provided in relation to the common stimulus space.
- Uses information in subject space to orient dimensions uniquely.

The INDSCAL Technique

The general type of MDS is essentially only one matrix of proximities. Since a matrix is a two-way array, it is called 2-way MDS. Three-way multidimensional scaling uses several matrices of proximities, which constitute a 3-way array and allows for larger systematic differences among the matrices. INDSCAL, Individual Differences Scaling, is such a method.

The data for INDSCAL consist of several proximity matrices. These matrices may represent different occassions on which proximities are measured, different conditions under which they are taken or proximities with respect to different characteristics.

Just as in MDS, INDSCAL determines a configuration of points called the group stimulus space. This space and the points in it do not exist for ordinary MDS. In principle, the co-ordinates of points in the weight space should always be positive, or zero. The distances among the points of the group space are not used by INDSCAL. Instead, a new confirguration is created for each subject and the distances in these configurations are used.

The INDSCAL Model

INDSCAL is a metric individual differences multidimensional scaling algorithm, using high speed computers. The model underlying INDSCAL maintains that all subjects view a common set of stimuli. Each subject observes differences among pairs of stimuli to be a function of the relative locations of the elements of the pairs on a set of perceptual dimensions, subsets of which are perceived in common by all subjects. The model considers that each subject may attach his own importances or weights to the various perceptual dimensions according to his own sensitivity to stimulus differences along the dimension.

A simple example may be considered. Two subjects A and B are presented with all possible distinct pairs of three cups of coffee, designated by numbers 1,2 and 3. Assume that the cups of coffee have the following physical properties.

Stimulus	Temperature, ^{o}F	Sugar,tsp
1	150	2.0
2	110	3.0
3	70	1.0

Upon presenting the subjects with the pairs of stimuli, they might have responded with magnitude estimates of the dissimilarity between the two cups in the pair. An artificial data of dissimilarities may be shown as

Subject A.

2	.84	
3	1.22	1.38
	1	2

Subject B

2	.88	
3	1.42	1.15
	1	2

This data would be analysed by INDSCAL to produce the results shown in figures 1-a and 1-b. Figure 1-a is the stimulus space in which stimuli are represented as points. The horizontal axis represents temperature and the vertical axis is a sweetness scale. In neither case are the scale projections linearly related to the physical properties of the stimuli. This is a characteristic of the perceptual processes involved when humans make judgements of differences between stimuli. The nonlinearity of the relationship portrayed between the physical properties and the perceived properties is thus often inherent in the data and is not a distortion caused by the INDSCAL model.

Figure 1-b shows the resulting subject space. Here subject A and B are represented as points having non-negative co-ordinate values on all axes. The co-ordinate

THE INDSCAL MODEL

COMMON
STIMULUS
SPACE X

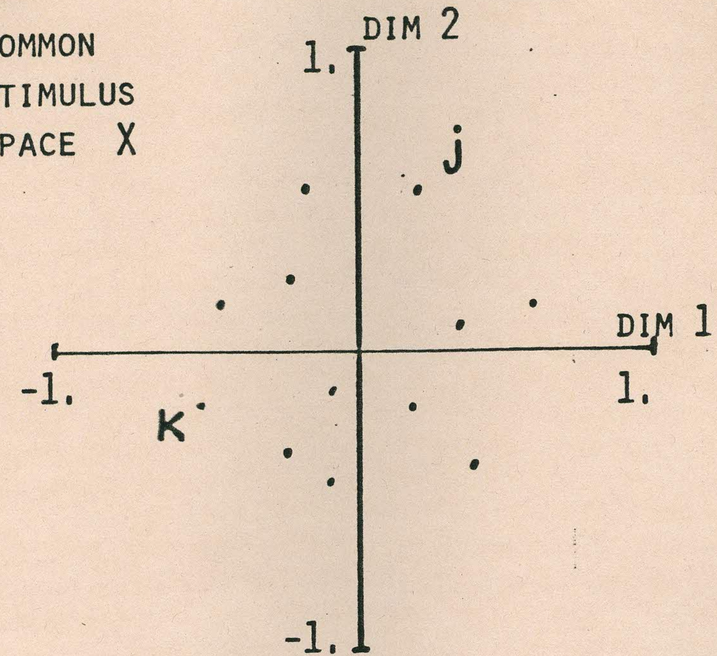


FIG. 1-a

SUBJECT SPACE W

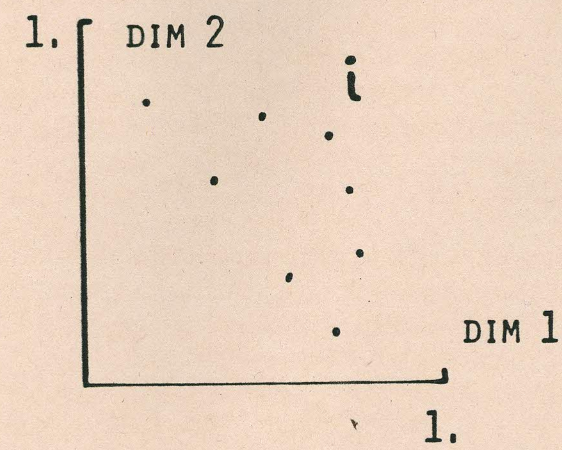


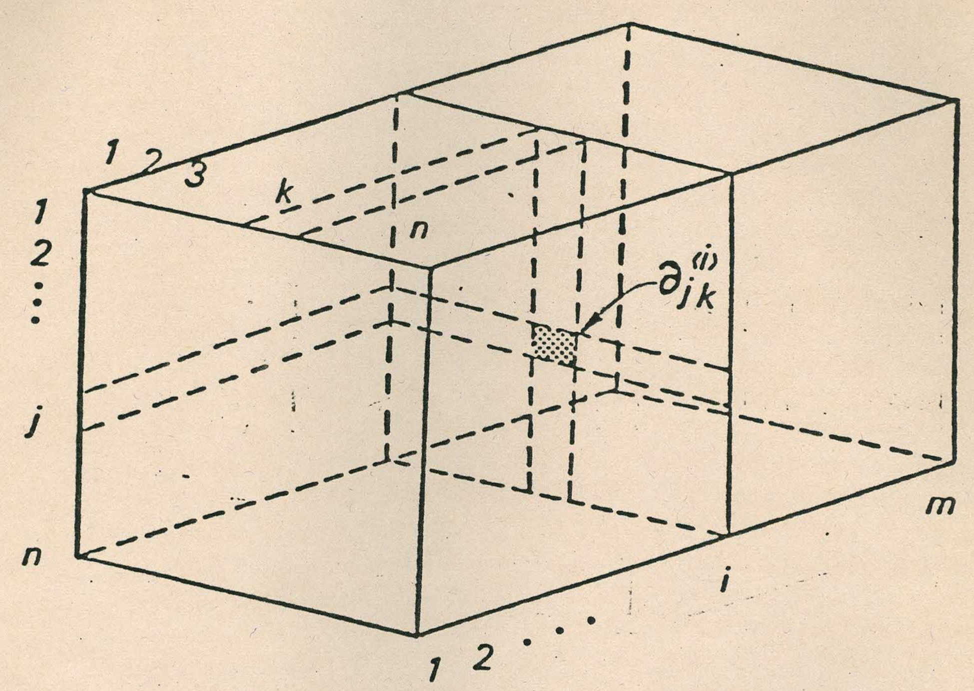
FIG- 1-b

$$D^{I}_{JK} = \left(\sum_{T} W_{IT}(X_{JT} - X_{KT})^2\right)^{\frac{1}{2}}$$

$(\sum_{T} W_{IT}^{2})^{\frac{1}{2}}$ IS THE CORRELATION BETWEEN THE INDSCAL MODEL AND THE SUBJECT'S DATA

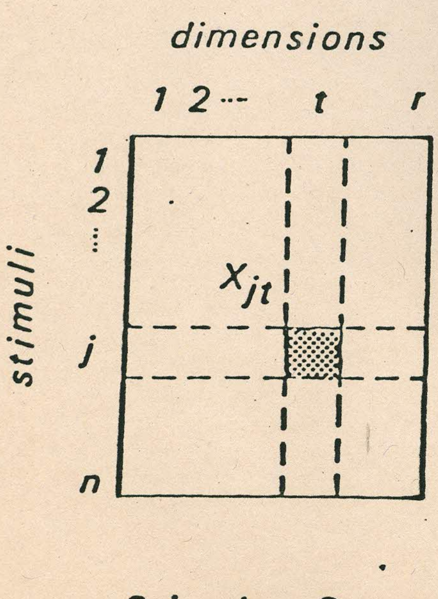
INDSCAL

INPUT

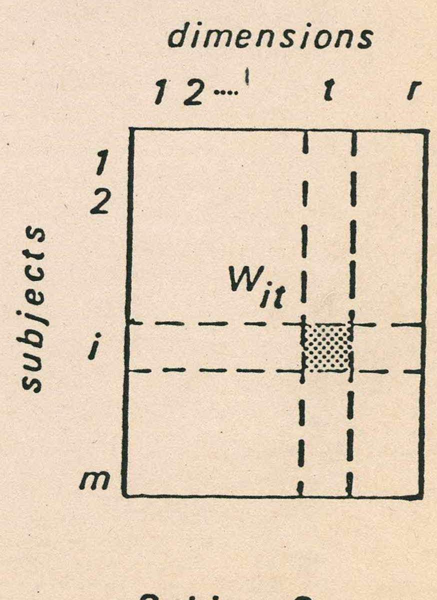


Input Matrix of Similarities Data

OUTPUT



Stimulus Space



Subject Space

Output Matrices of Stimulus and Subject Spaces values of a subject's point reflect his sensitivity to differences among stimuli with respect to the corresponding dimension in the stimulus space. It indicates that A is more sensitive to differences in sweetness than to differences in temperature. And the opposite is true for subject B.

The model thus scales the common stimulus co-ordinates on each dimensions, by different relative amounts most appropriate for each subject. One normalisation technique employed in INDSCAL ensures that all subjects have equal say in determining the final solution. This is accomplished by scaling the elements of the solar products matrix, which is derived directly from the data, for each subject such that the sums of squares of these elements are equal for all subjects. A second normalisation accomplished by INDSCAL, causes the length of a vector from the origin of the subject space to a subject's point to be an indicator of the product moment correlation between that subject's data and the INDSCAL model.

Methods of obtaining proximities data

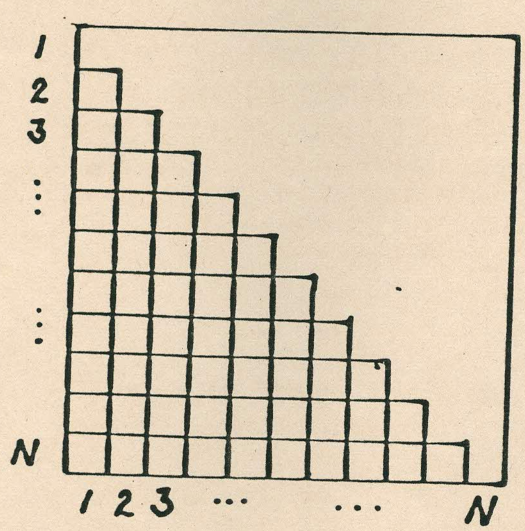
1. A common procedure for obtaining proximity data is to ask people to directly judge the psychological distance of the stimulus objects. Although similarity and dissimilarity are most frequently used to elicit the proximity judgements, alternative words are relatedness, dependence, association, complementarity,

TYPES OF DATA

1. PROXIMITIES DATA

SOURCE: THE SUBJECT IS PRESENTED WITH ALL (OR NEARLY ALL) POSSIBLE DISTINCT PAIRS OF STIMULUS OBJECTS

THE SUBJECT IS ASKED TO RESPOND WITH A NUMBER FOR EACH PAIR WHICH DESCRIBES THE <u>SIMILARITY (OR DISSIMILARITY)</u> OF THE MEMBERS OF THE PAIR.



FOR N STIMULUS OBJECTS THERE ARE:

N (N-1) / 2

DISTINCT PAIRS

USE: TO ESTABLISH THE LOCATION OF STIMULUS POINTS RELATIVE TO EACH OTHER substitutability etc. In order to discover, rather than impose, the dimensions, the attributes on which the stimuli are to be judged are usually not specified.

2. A simple method for relatively large stimulus sets or objects, is to have the responding subjects, sort, or cluster, the stimuli according to perceived similarity. The typical instructions are to place the stimuli into mutually exclusive and exhaustive categories so that stimuli in the same category are more similar to each other than to those in other categories.

3. Indirect measurement of proximity is also possible by presenting the stimuli in pair and asking if they are same or different. A matrix value is given for the number of same responses.

4. It is also possible to compute similarity from physical profiles like height and weight, gross national product, population etc.

The INDSCAL Methods

- Individual matrix for each subject is fed into the computer.
- Stimuli space and subject space are obtained.
- Yields information about both stimuli and individual subject participating in study.

The INDSCAL Process

1. Select product samples; may be a generic group like pens or specific group like micro-tip pens.
2. Determine primary attributes in the product.
3. Proximity data to be collected, as similarity/ dissimilarity values between pairs of samples. Number of pairs would be N(N-1)/2, where N is the number of samples.

   This would determine the relative location of stilulus points, as also the subject space.

In a different programme, called PREFMAP, preference between pairs of samples is also obtained in a rank order and fed into the computer. This provides information on the most preferred objects and how preference changes with distance from favoured object.

4. Subject's background data, would explain the basis of his judgements.
5. The products attributes are to be determined, by way of physical measurements, manufacturers data, form,

colour, price, etc. This would identify the dimensions which result from analysis of the proximities data.

Interpretation of Results

- Obtains the most important perceptual dimensions, and a rank order of all the dimensions.
- Sensitivities of the subjects.
- Proportion of preferences.
- Preference order of attributes
- Can identify features not considered important.
- Can determine group of features perceived as vital by a majority of subjects.
- determines how preferences change as subject groups change.
- determines what features appeal to which category of people.

Advantages of INDSCAL

1. Dimensions can be interpreted without rotating axes.
2. Data from different perceptual types presented in single and psychologically meaningful space.
3. Dimension values could be related to other factors of the product also, to obtain a solution to that factor.

The Experiment Conducted

Samples of 7 pens, of different types were collected. These were individually presented to four different subjects. The pens were presented in pairs; first one pen paired with all the others. This pen is kept away and the second pen is then paired with the remaining pens, and so on. A similarity figure is asked for each pair, giving 10 for maximum similarity and 0 for least similarity. A matrix as shown in fig. 4 is obtained . This is the data that is fed into the computer.

	COLO	PILOT	NESTLER	WOODEN	CRUSADER	SHARP	CAMLIN
COLO							
PILOT	4						
NESTLER	5	8					
WOOD.	1	2	1				
CRUS.	1	2	3	2			
SHARP	2	1	2	3	5		
CAM.	3	3	4	1	3	4	

SUBJECT- 1

	8						
	8	9					
	0	0	0				
	1	1	1	1			
	9	5	4	0	2		
	7	8	8	0	2	2	

SUBJECT- 2

COLO							
PILOT	7						
NEST.	7	9					
WOOD	1	2	2				
CRUS.	1	6	6	2			
SHARP	6	5	4	2	4		
CAM.	4	6	3	1	1	4	

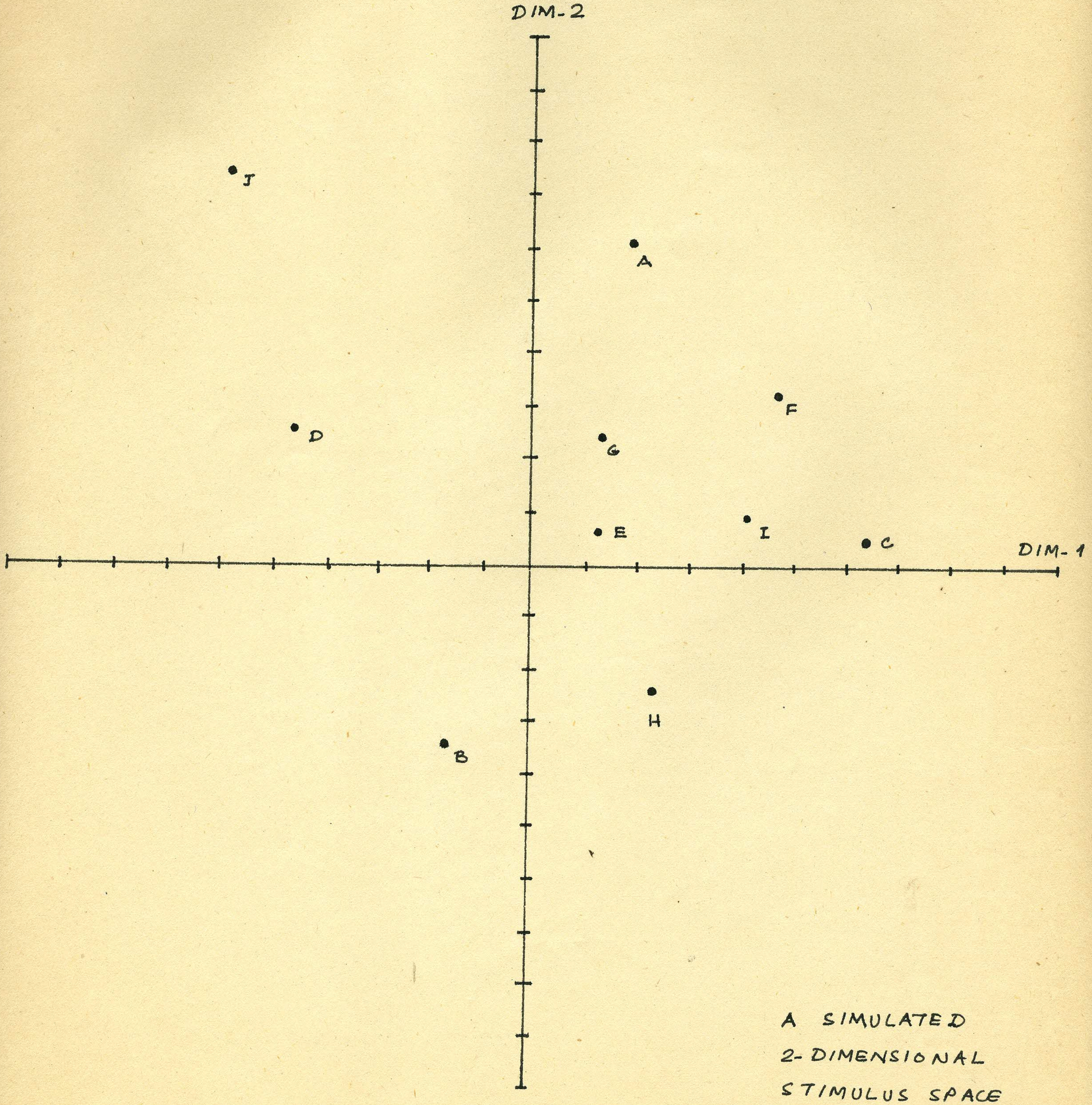
SUBJECT- 3

	7						
	9	8					
	2	3	2				
	3	5	4	3			
	5	4	5	2	3		
	6	8	6	2	4	6	

SUBJECT- 4

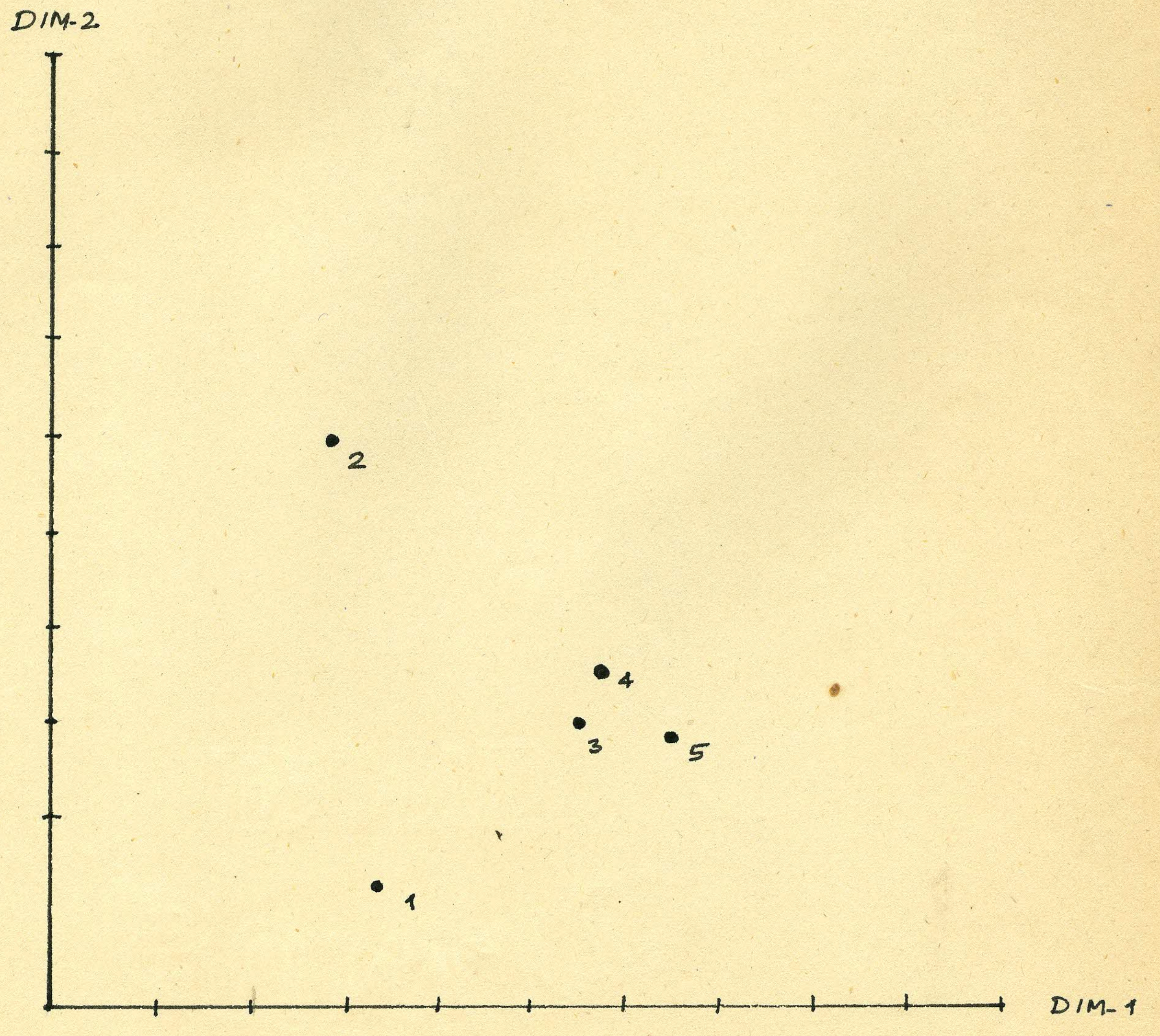
SIMILARITY DATA FOR SEVEN PENS
CONDUCTED ON 4 SUBJECTS
VALUES: MAX. SIMILARITY = 10
MIN. SIMILARITY = 0

FIG. 4



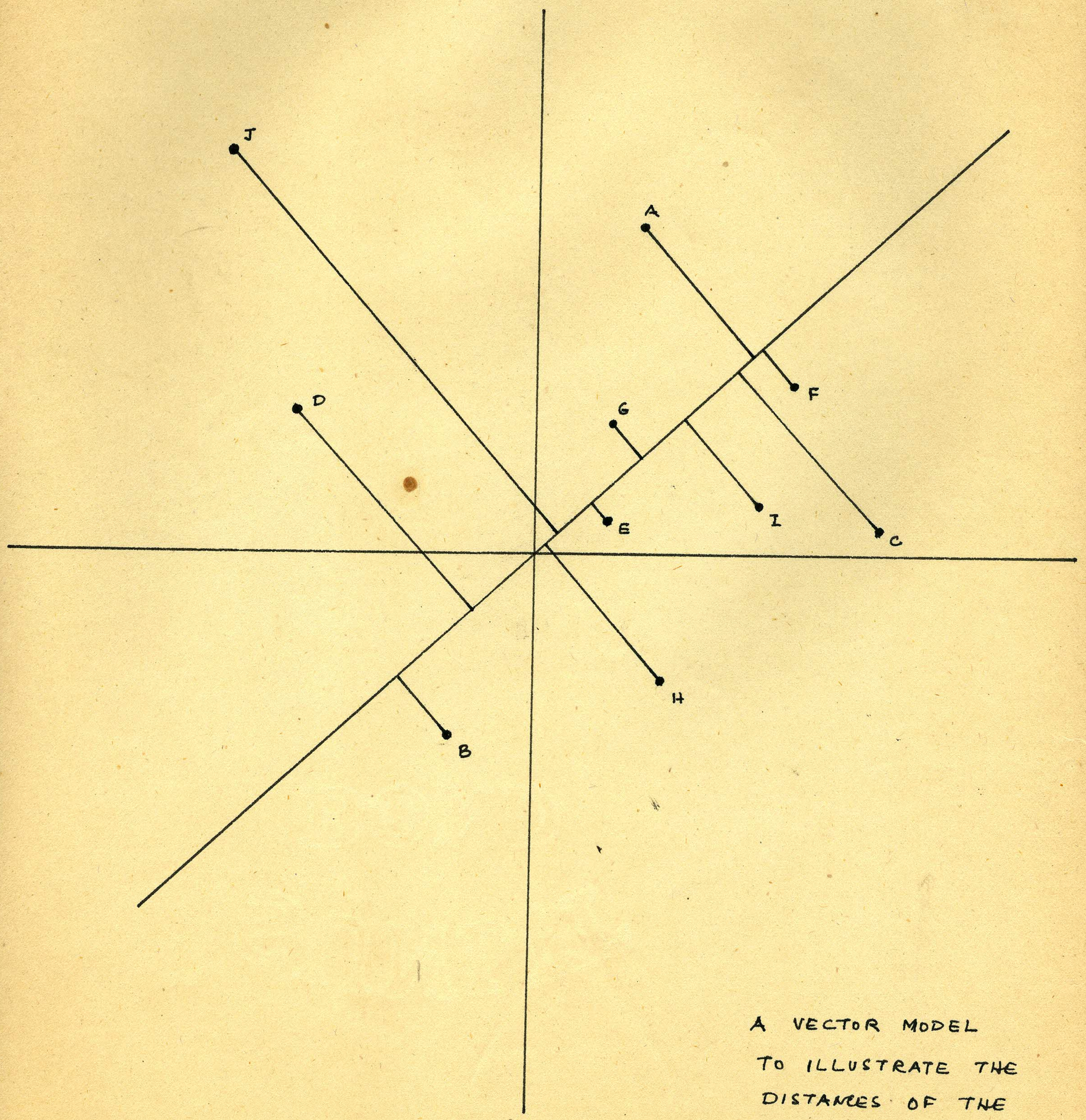
A SIMULATED
2-DIMENSIONAL
STIMULUS SPACE
FOR SAMPLES A TO J

FIG. 5



A SIMULATED SUBJECT SPACE
FOR 5 SUBJECTS

FIG. 6



A VECTOR MODEL TO ILLUSTRATE THE DISTANCES OF THE SAMPLES

FIG. 7

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