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**SWP 5/93 VALIDATING A METHOD FOR MAPPING MANAGERS'
MENTAL MODELS OF COMPETITIVE INDUSTRY
STRUCTURES**

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ABSTRACT

Cognitive mapping techniques refer to methods used to elicit the structure and content of people's mental models. There is a growing interest in applying these techniques to the study of managers' mental models of strategic management issues. This paper reports upon a new method for mapping managers' mental models of competitive industry structures, that is based upon recent developments in the cognitive psychology of the categorisation of concepts. This method, a simple visual card sorting technique, is quick to administer and interpret. The method is evaluated with respect to its psychometric properties against the well established, but potentially cumbersome, repertory grid technique. The method is demonstrated to have good validity by comparing it with the repertory grid technique.

INTRODUCTION

It is clear that people represent knowledge about their environment in the form of mental or cognitive models (cf. Bartlett, 1932, Schank, 1982, Lakoff, 1987, Johnson-Laird, 1989). These mental models are simplifications; heuristics that may be used to circumvent the limited capacity of short term memory (Miller, 1956) in searching long term memory for relevant information. It is for this reason that a more cognitive analysis of strategic management has developed (eg. Stubbart, 1989), alongside the more traditional economic analysis.

Within the cognitive approach to strategy, there has been, and continues to be, an interest in how managers categorize competitors (Porac and Thomas, 1990). There are a number of reasons for this interest. At a cognitive level, the way concepts are categorised has been implicated in the prediction of novel instances of a category (Anderson, 1991), decision making about concepts (Rips, 1975, Cherniak, 1984) and the way information about concepts is communicated (Edwards, 1991). Therefore, how managers categorise their competitors has very real implications for how managers, as individuals and as teams, analyse the competitive environment and how they take decisions about competitive strategy.

As well as justifications from the cognitive literature, the idea that companies operating with the same competitive arena can be categorized emerged in industrial economics over twenty years ago (Hunt, 1972). Categorisation based on objective economic indicators has become known as strategic groups theory (McGee and Thomas, 1986). However, the extent to which strategic groups theory produces category structures that are compatible with the implicit mental models of managers is not known, (Thomas and Venkatraman, 1988) although cognitive mapping techniques may be able to establish this.

The interest in how managers organise knowledge about their competitors has been justified by a consideration of both psychological theory and economic theory. An important avenue of research is to establish the validity of methods used to represent managers' mental models of competitive industry structures. It is the aim of this paper to address this issue by empirically testing the validity of a new method for representing managers' mental models of competition.

Cognitive mapping of managers' mental models of competitive industry structures.

With the shift towards a more cognitive analysis of strategy, a concomitant shift in methodology has emerged, such that cognitive mapping techniques are becoming increasingly popular in management research (Huff, 1990). Cognitive mapping techniques are methods used to assess the structure and content of peoples' mental models (Axelrod, 1976), showing how a person integrates information about his/her environment in graphical format (Fiol and Huff, 1992). Many of the techniques have been developed from research conducted in sub-fields of cognitive science, such as cognitive anthropology, artificial intelligence and linguistics (see Huff, 1990).

There exist a wide variety of cognitive mapping techniques, although only a few have been applied to assessing managers' mental models of competition. The cognitive mapping technique predominantly used to assess the structure of *individual* managers' mental models of competitive industry structures has been Kelly's repertory grid technique (Huff, 1990, used by Reger, 1987, and Walton, 1986). Another technique, based on hierarchical sorting methods has been used to map out collective beliefs within industries (eg. Porac, Thomas and Baden-Fuller, 1989). However, this latter technique is used to aggregate cognitive structures across individuals, rather than map individuals' mental models *per se*. A technique,

labelled visual card sort mapping, also purports to effectively map the way managers organise knowledge about their competitors.

Cognitive mapping techniques are a collection of tools rather than instances of standardized instruments, and thus standard validity data are not strictly applicable to these techniques (cf. Bannister and Mair, 1968). Nevertheless, desirable features of a cognitive mapping technique are acceptable psychometric properties, such as validity. Another desirable feature is that, ordinarily, the technique should be minimally intrusive to the research participant, without sacrificing any validity.

In the following sections, each of the mapping techniques applicable to the representation of *individual* managers' mental models of competitive industry structures will be described. Also, their theoretical underpinnings will be assessed, along with their practicability and known psychometric properties.

Repertory grid technique.

The repertory grid is a flexible technique for eliciting a person's mental model of a given domain. The technique is predicated by Kelly's construct theory (1955). The underpinnings of the theory are well-established, and have been described in detail elsewhere (Kelly, 1955, Bannister and Mair, 1968, Fransella and Bannister, 1977). However, the basic tenet of construct theory is that each individual seeks to predict and control events by forming theories about the way concepts relate to each other. Current work in experimental cognitive psychology, independent of construct theory, has begun to support this basic proposition, suggesting that people can categorise objects on the basis of *naive* theories (Medin, 1989, Rips, 1989).

The first stage of the technique involves *eliciting the elements* (eg. asking the respondent to name the companies s/he believes her firm is competing with). The

next stage involves eliciting the *constructs*. Constructs are the qualities that people use to think about the elements; constructs are the descriptors of the elements. In order to elicit the constructs, the method of triading is used. Triading involves selecting three cards at random. The respondent is asked to identify the two companies that are most similar, and then to state how these two are different from the third. After the interview, the companies and constructs are then arranged into a grid. The respondent then rates each of the companies on each particular element.

A map of the respondents mental model may be produced by subjecting the grid to principal components analysis and/or cluster analysis (Smith and Stewart, 1977). Cluster analysis shows how the elements are grouped together. Principal components analysis produces a map that shows the underlying dimensions that differentiate between the elements. However, these techniques can involve some subjective interpretation on the part of the researcher. Moreover, there exist a wide variety of techniques labelled cluster analysis (Everitt, 1980), thus making it difficult to choose the appropriate technique. Thus the adequacy of any maps constructed from repertory grid is dependent upon the ability of the data to meet the underlying assumptions of the chosen statistical technique of construction. Examples of cluster analysis derived and principal components analysis derived grid maps are shown in figure I.

INSERT FIGURE I HERE

In terms of practicability, grid technique may take some time to complete, since it involves triading and the administration of the grid. This may be a substantial problem if the number of elements is large. Participants may also find the procedure somewhat annoying, because the process of triading (Brown, 1992). For these reasons, the relative intrusiveness of the technique may create difficulties in

obtaining access to some executives, since they may be unwilling to donate too much time to the researcher.

Despite criticisms concerning the construction of maps, and the practicability of the technique for competitive mapping research, grid technique has a number of advantages. The technique has been shown to be reliable by producing similar representations, over time, of a person's mental model (Bannister and Mair, 1968). Moreover, Bannister and Mair assert that sometimes the very fact that grid structures (and hence mental models) change over time is usually the topic of interest. Similarly, Bannister and Mair cite evidence suggesting that grid technique has acceptable validity when evaluated within the confines of standard psychometric assessment, although grid technique attempts to go beyond the limitations of normative assessment. Another advantage of grid technique is that it rests upon a well established and well articulated theory of psychology (cf. Garg-Janardan and Salvendy, 1988), although flexibility in the assumptions underlying the cognitive structure of the map is retained (Smith and Stewart, 1977).

Producing a visual map of a person's mental model.

The visual card sort technique described here is based on cognitive categorisation theory, given the impetus provided by strategic groups theory and previous cognitive analyses of competitive industry structures (see above). Initial conceptions of managerial categorisation (Porac *et al*, 1989) were based on the hierarchical model of Mervis and Rosch (1981). However, developments within cognitive psychology have suggested that concepts are not necessarily cognitively organised in hierarchies (Collins and Loftus, 1975), especially in expert knowledge domains (Murphy and Wright, 1984, Gammack, 1987, Tanaka and Taylor, 1991). Nevertheless, experimentally established principles of cognitive categorisation are evident: Firstly, categorisation is almost always probabilistic, with some members

of a category being closer to the central tendency of a category than others (Smith and Medin, 1981). Secondly, category structures can be context dependent, such that different situations may lead a person to categorize the same objects in different ways (Barsalou, 1982). Finally, categorisation may take place by matching the features associated with category membership, or by applying naive theories about the nature of the world (Medin, 1989).

It is necessary to produce a representation of a person's mental model that is consistent with these complex empirical findings. Therefore, a flexible method is required in order to be consistent with the flexible nature of human categorisation. One method that meets this requirement involves a visual card sorting task which shows how people categorize concepts within a particular knowledge domain (Canter, *et al*, 1985, Gammack, 1987, McKeown and Thomas, 1988).

The technique requires the respondent to name all those companies that she can think of that compete with her own company. This stage is equivalent to the *element eliciting stage* of the repertory grid technique. The names of the elicited companies are written on cards.

The respondent is then asked to sort the cards, such that those companies that compete most closely with each other are placed most closely together. The respondent is then asked why s/he placed the cards in this manner. In this way, the technique provides a quick and face valid way of representing the relationships between companies in an industry. The technique also provides descriptions of each of the companies or clusters of companies, depending upon how the cards are arranged.

As it stands, the technique is constrained to show just one picture. Therefore, the technique may lose some of the context sensitivity of mental models. This is easily

overcome if the respondent is asked if she would wish to produce other ways of arranging the cards. Thus it is possible to elicit multiple maps from one respondent (Canter *et al*, 1985).

Each of the maps can be recorded by simply taking a photograph of the map. The labels that the respondent gives to each of the clusters of companies can be tape recorded and written down. From these sources of data, a map may be constructed that shows the way in which the companies were arranged, together with the descriptors used to label those companies. An example of a visual card sort map is shown in figure II.

INSERT FIGURE II HERE

The technique is potentially very easy to administer and minimally intrusive. Moreover, the technique is compatible with the cognitive psychology of categorisation (see above) and does not require the application of statistical procedures to produce the maps. However, although card sorting methods have a long history in psychology (Canter *et al*, 1985), it is not known whether visual card sorting can be applied to the study of managers' mental models of competitive industry structures. Thus the validity of this technique is not yet known in this knowledge domain. Therefore, the rest of the paper will be given over to testing this property, and also the practicality of this technique. This is to be achieved by comparing the visual card sort technique with the established repertory grid procedure.

METHODS

Participants.

Participants in the study were drawn from three industries each concerned with pumps supplied to the North Sea off-shore oil industry. The first industry to be sampled consisted of senior managers from companies that manufacture such pumps. Initially, ten companies were approached at managing director level asking for co-operation. Five companies agreed to co-operate out of these ten, giving access to twenty five managers. Between three and eight managers were interviewed per company from this industry, representing a range of senior managerial functions, such as managing director, sales and marketing director, manufacturing director and finance director. This sample was contacted again for follow-up interviews, of which 24 managers out of the original 25, were able to participate.

A sample was also drawn from the off-shore contracts engineering industry. Companies operating in this industry build oil rigs for oil companies, and thus have to buy pumps for these rigs. Again, initial contact was made at the level of managing director, but interviews were conducted only with those people with knowledge of the off-shore pump industry. Out of seven firms contacted, four agreed to participate, allowing access to eight managers, who were either purchasing managers or engineering managers. The final sample also consisted of purchasing and engineering managers with knowledge of the off-shore pumps industry, but were drawn from oil companies. Nine companies were contacted at managing director level, of which six agreed to participate, allowing access to nine managers.

Thus a total of 42 managers were interviewed initially (although two managers did not provide full information, and so their data were discarded). Twenty four of these managers were interviewed a second time (of which 22 provided usable data). All the sample were male. They had been working in their present position for an average of 4.27 years (std dev = 5.12), working for their company for an average of 10.44 years (std dev = 6.66) and had been working for their industry for an average of 16.78 years (std dev = 7.93).

Procedure.

Each of the participants was administered a semi-structured interview, that usually lasted less than half an hour. The purpose of this interview was to uncover the participants' mental models of the relationships between competitors in the North Sea off-shore pump industry. During the semi-structured interview, both the visual card sort technique and construct and element elicitation phases on grid technique were implemented. The element elicitation phases of visual card sort mapping and grid technique are identical. It was assumed that constructs elicited by visual card sort mapping would have been supplied by the triading phase of grid technique anyway. Thus these constructs were used in the administration of the repertory grid.

Repertory grids were administered by postal questionnaire a few days after the initial interviews. Out of 40 questionnaires distributed, 35 were returned (a response rate of 87.5%). In addition to the grids, participants were asked to rate the importance of each of their constructs in assessing competition, on a five point, fully anchored Likert type scale (1 = Very unimportant, 5 = Very important).

In the follow-up interviews, twenty four managers from the pump manufacturing industry were presented with a random sample of maps. Participants were asked to

rate the similarity of each of the maps to their own mental model of the competitive structure of their industry. That is respondents were asked to compare each of the maps with their *own cognitive structures at that point in time*, rather than a representation of those cognitive structures. Ratings were made on a five point fully anchored Likert type scale (eg. 1 = The same as my view of the competitive environment, 5 = Not at all similar to my view of the competitive environment).

Asking respondents to rate the similarity of maps to their own cognitions is one way of checking the validity of the mapping technique (Huff and Fletcher, 1990). This technique rests on the basic premise that people can recognize maps of their own mental models. Thus, in this study, people should rate maps elicited from themselves as being more similar to their own mental models than randomly generated maps based on elements supplied by the participant her/himself, if the mapping technique is valid. In this study, this technique has been improved by embedding the target maps and the random maps amongst a random selection of other maps elicited from other people.

The maps were presented in blocks consisting of all the visual card sort maps, all the principal components analysis maps and all the cluster analysis maps. Within these blocks, the respondent was presented a random selection of maps, consisting of their own maps, a selection of other peoples' maps and maps randomly generated for each respondent from the elements they provided. Maps were presented in random order within blocks, and blocks were also presented in random order.

The follow-up interviews took place between five and seven months after the initial interviews. It is therefore unlikely that respondents remembered the way they arranged the cards in the first interview, thus removing bias due to recall.

RESULTS

Assessing the validity of the technique.

The validity of the technique was assessed in three ways. Firstly, the average importance of the constructs elicited from visual card sort mapping was compared to those elicited from triading. Secondly, numerical comparisons were made between the category structures elicited by visual card sort mapping and those derived by cluster analysis of repertory grids. Finally, participant self-ratings of similarity to one's own cognitive structures were compared.

A related t-test was used to assess any differences in the rated importance of the constructs elicited by visual card sort mapping and by triading. An average for each type of construct was taken for each participant, the means and standard deviations of which are shown in Table I. Only 29 participants, out of 35 who responded to the questionnaires, had provided constructs elicited by triading as well as visual card sort mapping, thus the related t-test was applied to these 29. The result of the test was not significant ($t=1.03$, $df=29$, $p>.10$), indicating that visual card sort mapping produces constructs as least as important as those elicited by triading. Moreover, as can be seen from Table I., the means for both types of construct are high, in relation to the five point scale, indicating importance. Thus the results suggest, within the context of competitive mapping, both techniques are eliciting non-trivial constructs.

INSERT TABLE I HERE

Objective comparisons between the category structures produced by visual card sort mapping and cluster analyses of repertory grids were produced by the application of

a formula for comparing categories introduced by McKeithan *et al* (1981). The formula estimates the dissimilarity between two category structures thus:

$$D = 1 - ((\ln(a + 1)) / (\ln(b - 1)))$$

Where D is the dissimilarity, a is the total number of elements that are placed in the same categories in both maps and b is the total number of elements (ln is the natural logarithm). Thus, according to this formula, two maps are *exactly the same* if D is equal to zero, and are *maximally dissimilar* if D is equal to one.

Category structures were derived from repertory grids by applying the average linkage between groups clustering method using the squared Euclidean distance. The clusters were defined at that level of the agglomeration schedule where the largest difference was observed between two steps (Norusis, 1988). These cluster analysis derived maps were compared with the primary, secondary and lower order maps (if produced) elicited by visual card sort mapping.

It was found, by applying the McKeithan *et al* formula, that the average coefficient of dissimilarity between grid derived maps and visual card sort maps was 0.144 (std dev = 0.141), if the coefficients of dissimilarity are averaged within each participant first (for those with more than one visual map). This value was found to highly significantly different from one ($t=35.40$, $df=34$, $p<.001$). Since testing the significance of the difference between one and the average value of the dissimilarity coefficient is analogous to testing the significance of a correlation, it may be assumed that both mapping techniques produce convergent results in terms of category structures at least. This is supported by the very large size for t and the proximity of the average value of the coefficient of dissimilarity to zero.

In order to test differences between self-rating data of similarities between elicited maps and random maps to managers' own mental models, the self-rating data were subjected to a repeated measures analysis of variance (ANOVA), with two factors, mapping technique (visual card sort map, principal components derived map and cluster analysis derived map) and who the map belonged to (the participant or a random map derived from the elements the respondent himself supplied). In this analysis, for managers that had produced two visual card sort maps, an average rating was taken, otherwise the rating of the primary map was used for those managers who only produced one such map. The means and standard deviations for these analyses are shown in Table II.

ANOVA revealed a significant main effect for whether the map was a random map or not ($F=11.20$, $df=1/21$, $p<.005$). This indicates that participants were discriminating successfully between their own maps (regardless of how they were produced) and the random maps. An examination of Table II. indicates that participants were consistently rating their own maps to be more similar to their own mental models than the random maps, thus indicating the validity of the visual card sort technique. This overall main effect also indicates the validity of using self-rating data for assessing the veracity of cognitive maps, since repertory grid derived maps have been validated previously (Bannister and Mair, 1968).

The interaction effect between the type of map and who the map belonged to was not significant ($p>.25$). This indicates that although participants can discriminate their own maps from random maps, visual card sort mapping is neither superior nor inferior to repertory grid derived maps. The result also indicates that self-ratings were not influenced by recall of the original interview, since participants' own visual maps were not rated significantly higher than participants' grid derived maps (participants would not have seen their grid derived maps before). The main effect for type of map was also not significant ($p>.10$).

Practical considerations and inter-rater reliability.

It was found that the participants could complete the visual mapping procedure very quickly, typically from start to finish in less than five minutes. Arranging the cards themselves usually took less than thirty seconds per map per respondent.

In contrast, repertory grid technique took much longer to administer, usually between fifteen and twenty minutes. This is in addition to the time it took to elicit elements and constructs from visual card sort mapping. Thus visual card sort mapping, compared to grid technique, is minimally intrusive, quick to administer and potentially less irritating for participants to complete.

Inter-rater reliability was assessed by comparing the maps constructed from the interview data by two independent coders (the first and second authors). In the construction of the visual card sort maps from 42 participants, coders disagreed only on minor aspects of three maps. These disagreements were easily resolved by consulting back to the initial interview tapes and notes. Thus the inter-rater reliability of the technique was found to be very good. This high inter-rater reliability may be attributed to the well-defined structure of the technique and double checking carried out with participants during the interview. Moreover, inter-rater reliability is expected to be high since the technique requires participants to make their cognitive structures explicit, rather than researchers inferring them from secondary sources.

DISCUSSION

Discussion of results.

The results of the study indicate that the new visual card sort technique is at least as valid as the established repertory grid procedure (Bannister and Mair, 1968) in mapping managers' mental models of competition. The results supporting this contention may be summarized as follows: a) Constructs elicited by visual card sort mapping are at least as important for evaluating competitors as those elicited by triading: b) The coefficients of similarity between the cluster analysis derived maps and the visual card sort maps were close to maximal similarity and very different from maximal dissimilarity: c) Participants successfully discriminated between their own maps, regardless of whether they were derived from repertory grids or elicited by visual card sort mapping, and randomly generated maps.

A comparison of visual card sort mapping with repertory grid technique.

Although the psychometric properties of visual card sort mapping are acceptable in comparison to grid technique, the technique is quicker than grid technique and relies on participants mapping their own cognitions, rather than maps being inferred via statistical procedures. However, the method of triading produces more constructs than visual card sort mapping, so grid technique may be assumed to produce far more detailed maps than visual card sort mapping.

There are two implications of these conclusions. Firstly, since visual card sort mapping is quicker, less intrusive and potentially less irritating than grid technique, visual card sort mapping may be more appropriate for research and consulting purposes where access to managers is limited and/or faced with heavy time constraints. In these circumstances, visual card sort mapping may be considered to

be analogous to short form variations of normative instruments (eg. the GHQ12 as derived from the GHQ60, Goldberg and Williams, 1988).

Secondly, since grid technique may elicit more detailed knowledge, where time and resources allow, grid technique should be used. However, it may be appropriate to use grid technique in conjunction with visual card sort mapping. There are three arguments for using both techniques. Most practically, there is nothing to be lost by visual card sort mapping as a precursor to grid technique. If anything, by conducting visual mapping first, many important constructs will be elicited more quickly, thus saving time.

The second argument in favour of using visual card sort mapping in conjunction with repertory grid is methodological. Olson and Reuter (1987) consider that methods for representing knowledge can be divided into direct methods and indirect methods. Direct methods ask the respondent to directly articulate his/her knowledge. Thus visual card sort mapping may be described as a direct method. In contrast, indirect methods rely on recall or scaling responses to infer the structure of an individual's mental model. Therefore, grid technique may be thought of as an indirect method. Thus, given the differing assumptions of direct and indirect methods, it is best, where possible, to use both, in order to increase the validity of measurement (Cook and Campbell, 1976).

The third argument in favour of using both techniques in conjunction is theoretical, in that it relates to the type of knowledge each method is eliciting. Visual card sort mapping elicits 'top of the head' category structures; that is the way the relationships between competitors may be represented in short term memory most readily, since all competitors are considered at once. These 'top of the head' category structures may represent the means by which managers most often

communicate knowledge about their competitors to other managers (cf. Edwards, 1991).

In contrast, grid technique requires participants to make considered comparisons between specific instances via the method of triading. Thus grid technique can require participants to process deeper conceptual relations, and may therefore build a picture of how the elements relate to each other in semantic memory. It is thought that cognitive categorisation takes place by the application of naive theories about how concepts relate to each other (Murphy and Medin, 1985, Rips, 1989), although categorisation based on feature matching may also occur (Medin, 1989).

Smith, Shoben and Rips (1974) proposed a two stage model of categorisation, where feature matching provides a quick means of categorisation, and categorisation based on deeper conceptual properties is more reliable (but is slower). Thus visual card sort mapping may represent knowledge that is easily and often accessed by short term memory (stage one of Smith *et al*'s model), but grid technique may elicit deeper knowledge that is not accessed by short term memory as often (stage two of Smith *et al*'s model).

Summary.

The results presented in this paper indicate that visual card sort mapping is a valid method for mapping managers' mental models of competitive industry structures. For theoretical, methodological and practical purposes, it is considered that visual card sort mapping should be used in conjunction with grid technique for most purposes. However, when ease of access to managers is constrained or time constraints great, the convergence between maps elicited by visual card sort mapping and those elicited by grid technique indicates that visual card sort mapping may be used by itself, with relatively little loss of information.

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TABLE I. Means and standard deviations of averaged rated importance for constructs derived from visual card sort mapping and triading. Data are shown for 29 respondents who supplied constructs by triading as well as visual card sort mapping.

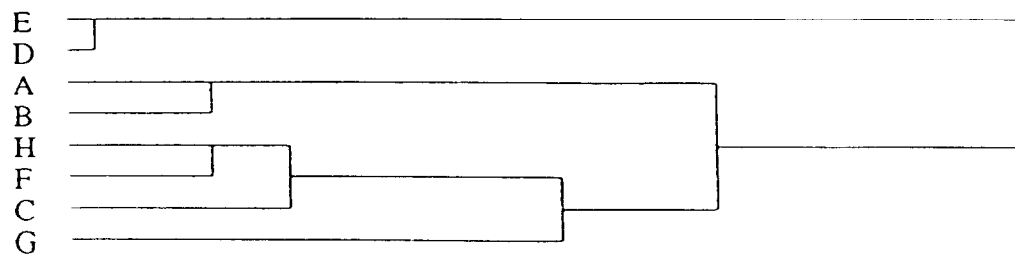
Type of construct	Mean	Standard deviation
Visual card sort mapping	3.91	0.565
Triading	3.75	0.715

TABLE II. Means of self-rating data (standard deviations shown in brackets).

	Own maps	Random maps
Mapping technique		
Visual card sort	1.87 (1.01)	3.27 (1.20)
Principal components	2.50 (1.26)	3.50 (0.86)
Cluster analysis	2.50 (1.23)	3.05 (1.43)

FIGURE 1. Examples of cluster analysis derived and repertory grid analysis derived repertory grid maps (company names have been removed).

a) Cluster analysis map.



b) Principal components analysis map.

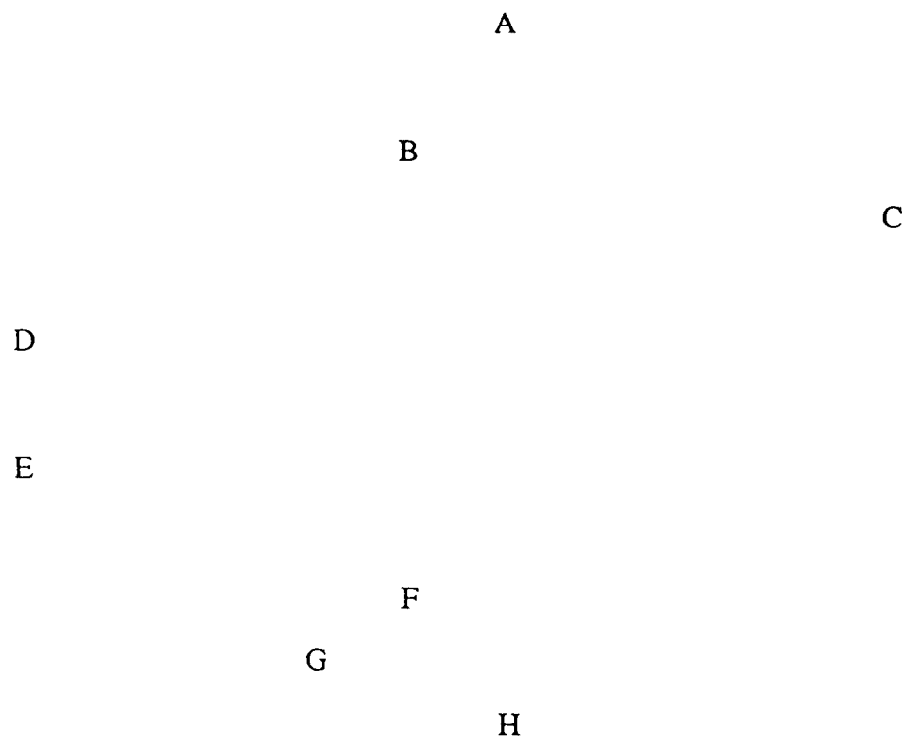
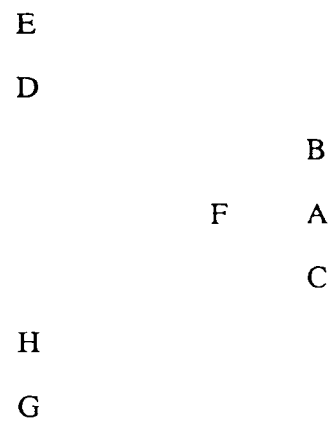
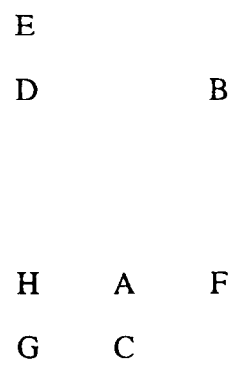


FIGURE II. Examples of visual card sort maps.

Example a)



Example b).



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