

# COGNITIVE MAPPING AS A TOOL FOR REQUIREMENTS CAPTURE

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This paper describes the application of cognitive mapping techniques, for eliciting and representing cognitive structure, to the problem of user requirement capture for the design of an electronic database. The research is based upon the assumption that organising information so as to be compatible with the structure of users' knowledge will enhance information retrieval by supporting more effective navigation behaviour. Although several researchers have noted the potential of cognitive mapping techniques, previous research has generally failed to address serious methodological problems associated with their application to design. A methodological approach is devised which addresses these problems, and thereby enhances the utility of the techniques as tools for user requirement capture.

## Introduction

### *Information Retrieval*

In recent years, there has been an enormous increase in the quantity and variety of information stored in electronic databases. As they become increasingly large and complex, the task of retrieving information from these databases is becoming increasingly difficult. Such information retrieval problems are likely to be associated with low task quality and high user (and system) costs; including slow and error-prone task performance, and low user satisfaction.

The take-up of database-centred electronic services, such as teleshopping, is therefore likely to depend, at least in part, upon customers being able to find the desired - or **target** - information quickly and easily. Users may adopt one of a number of retrieval strategies (such as 'searching' and 'browsing'), each of which depends to varying degrees upon effective navigation around the database. Database 'navigability' is therefore likely to be an important user requirement for the design of the user interface (UI) to large databases of product information supporting electronic teleshopping.

### *The Design Problem*

Electronic databases are commonly organised into hierarchical menu structures. The process of partitioning large amounts of complex and varied information into discrete categories presents two overlapping problems:

- **Fuzzy Groups:** real-world objects may often be grouped in a variety of ways depending upon the context, and the groups so formed are often over-lap. For example, a 'vege-burger' may be categorised either as an instance of a burger (along with hamburgers etc.), a frozen food (along with pizzas etc.), or a vegetable product (along with carrots etc.). Indeed, several studies have demonstrated that people take significantly longer to select the correct menu category when the target item is a less familiar example of the category (e.g. Somberg and Picardi, 1983).

- **Fuzzy Labels:** labels for large and ill-defined groups of items are often obscure and inaccurate (over or under-inclusive). For example, Lee et al. (1984) reported that fuzzy category labels such as 'miscellaneous' created confusion and uncertainty among users.

### *Compatibility*

A number of researchers have recognised the importance of achieving a 'fit' between the design of the user interface to an electronic database, and the structure of users' knowledge of the content of the database (e.g. Roske-Hostrand and Paap, 1986). The present research is based upon the assumption that organising a database UI such that it is compatible with users' structural knowledge - or **cognitive structure** - will enhance information retrieval by supporting more effective navigation behaviour. In addition, it is assumed that rapid and error-free retrieval of product information will enhance user satisfaction and may thereby increase the uptake of database-centred electronic teleshopping services among the potential user population.

### *Cognitive Mapping*

Techniques for eliciting and representing cognitive structure are based upon the assumption that 'similarity data' - describing the relationships between a set of stimuli - provides an index of the organisation of these concepts in human memory (e.g. Fillenbaum and Rapoport, 1971). The validity of the representations generated by these techniques - or **cognitive maps** - is, however, compromised by several methodological limitations. These limitations must be overcome if cognitive mapping techniques are to provide a useful tool for informing design.

The methodological problems associated with the application of cognitive mapping techniques, together with the steps adopted in the present study to resolve them ( *in italics* ), are outlined below.

- **stimulus selection** - previous research has generally failed to provide explicit a priori criteria for the selection of a comprehensive and representative stimulus set.

*An analytic framework for characterising the grocery shopping domain was devised to provide an explicit rationale for stimulus selection.*

- **contextual effects** - since similarity judgments are likely to be sensitive to contextual variables, different cognitive maps may be elicited in different situations.

*A relatively simple, rapid and unconstrained elicitation procedure - 'free card sorting' - was employed, leaving subjects free to determine their own criteria of correspondence.*

- **choice of representational model** - different statistical models for representing similarity data are based upon different assumptions, tend to reveal different aspects of cognitive structure, and may have 'Procrustean properties' which may impose inappropriate structure upon similarity data (Fillenbaum and Rapoport, 1971).

*Both **spatial** [multidimensional scaling] and **network** [hierarchical clustering] analyses were employed to provide contrasting representations of cognitive structure.*

- **interpretation** - although elicitation techniques are associated with formal analytic tools which generate visual representations of similarity data, the process of interpreting cognitive maps remains largely subjective.

*The card sorting procedure was combined with more 'qualitative' elicitation techniques, including concurrent and retrospective **verbal protocols** and direct observation, to provide a fuller picture of cognitive structure and facilitate interpretation.*

## Stimulus Selection

The validity of a cognitive map depends critically upon the selection of a representative and comprehensive set of stimuli. This in turn depends upon an understanding of both cognitive structure, and of the domain of real world objects to which this knowledge corresponds.

### *Cognitive Structure*

After Rosch (e.g. Rosch et al., 1976), grocery object categories can be characterised as having both a 'horizontal' within-category and a 'vertical' between-category structure. Within-category structure is assumed to be based on a hierarchy of levels of abstraction, with a **basic level**: "that is appropriate for using, thinking about, or naming an object in most situations in which the object occurs" (Rosch and Lloyd, 1978). Between-category structure is thought to be based upon typicality; with typical category members (or **exemplars**) being the most familiar, the most easily and accurately classified, the most likely to be elicited as category instances in free recall, and the most likely to be used as cognitive reference points in comparisons.

The stimulus set should therefore consist of basic level exemplars sampled from each of the principal super-ordinate categories of grocery object.

Rosch has pioneered the use of a **free-association** procedure for generating category exemplars. The technique is based on the assumption that the items cited most frequently as examples of a particular category are the most typical category members.

The use of a free association procedure for stimulus selection demands that the principal super-ordinate categories of grocery object be first identified. An analysis of the domain of grocery objects was therefore conducted in an attempt to elucidate the nature of grocery categories.

### *Domain Analysis*

After Dowell and Long (1989), the grocery shopping domain can be characterised as consisting of **grocery objects** (e.g. apples and bacon), and **people's shopping needs** (e.g. fully or partly specified objects on an implicit or explicit shopping list). The foregoing analysis also addresses the supermarket worksystem; consisting of **shoppers** (users) and **supermarket devices** (e.g. displays and trolleys).

Grocery objects are defined by a number of attributes [A]<sup>1</sup> (see table 1).

In the context of the supermarket worksystem, grocery objects also have the attribute of location [A]; which is determined by the interaction of the attributes of grocery objects with those of worksystem devices. For example, frozen (nature [A]) grocery objects are located in freezers; while fresh (nature [A]) grocery objects are located in gondolas and chillers.

Grocery shopping needs are specified in terms of the attributes of grocery objects.

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<sup>1</sup> In order to enhance clarity of the foregoing discussion, the symbol "[A]" is employed to qualify every reference to **an attribute of a grocery object**.

| [A]        | example   |
|------------|-----------|
| appearance | red tin   |
| brand      | Heinz     |
| name       | tomatoes  |
| nature     | canned    |
| price      | 40p.      |
| quantity   | 12 oz.    |
| type       | vegetable |

Table 1. Principal Grocery Object Attributes [A]

Each grocery object attribute may have a range of possible values: for example, nature [A] may have the values of either **frozen, fresh, dried or canned** [where 'canned' includes all grocery objects which are packaged in tins, bottles, jars, and tubes]. The value of a grocery object's type [A] is expressed in terms of the 'class name' of the grocery object. Analysis of a domain instance in the supermarket worksystem revealed 23 values of grocery object type [A] (see table 2.).

|                       |                |             |
|-----------------------|----------------|-------------|
| bakery products       | fruit          | ready meals |
| biscuits              | fruit juice    | salad       |
| cereals               | herbs & spices | sauces      |
| cooking ingredients   | hot beverages  | snacks      |
| dairy produce         | meat           | soft drinks |
| delicatessen products | pickles        | soup        |
| desserts              | poultry        | vegetables  |
| fish                  | preserves      |             |

Table 2. Values of the type [A] of grocery objects

Different attributes correspond to different levels of abstraction in the structure of grocery object categories. A grocery object's **name** [A] (e.g. tomatoes) will generally correspond to Rosch's basic level of abstraction - especially for highly differentiated grocery categories (such as 'fruit' and 'meat'). Grocery object **type** [A] (e.g. vegetable) and **nature** [A] (e.g. canned), in contrast, will generally be associated with the more abstract, super-ordinate levels of category structure.

## Procedure

### *Free Association Task*

A group of 10 subjects were asked to generate an instance of each of 23 values of grocery object type [A] and the 4 values of grocery object nature [A]. The single most frequently cited instances of grocery object type [A], together with the 3 most frequently cited instances of grocery object nature [A], were selected - giving a total of 35 (23 + 12) grocery object exemplars.

For example, 'bread', 'rolls', 'pastries', and 'cakes' were all cited as instances of **bakery products**. Since 'bread' was cited by a total of 7 subjects, it was deemed to be the most prototypical exemplar and was therefore selected as a stimulus item.

The names of the selected grocery objects were printed on pieces of white card to be used as the experimental stimuli.

### Card Sorting Task

One hundred subjects were asked to sort the 35 stimulus cards into as many groups as they wished, putting "similar ones together". Subjects were asked to describe the reasons for their similarity judgements (concurrently), and to label the groups and sub-groups so formed (retrospectively).

### Data Analysis

A group similarity matrix was derived from the card sorting data and transformed into a chi-square dissimilarity coefficient matrix for input into SPSS-X 6.1. Group solutions were then derived for both standard non-metric Multi-Dimensional Scaling (MDS) and between-group linkage Hierarchical Clustering (HCA) procedures.

## Results

SPSS provides several numeric formal measures of 'fit' (see table 3.) which suggested that the 3D solution provided the most appropriate solution - explaining over 96% of the variance in the similarity data (RSQ) with a stress value of only 8%. However, these fit metrics are only heuristics, and the most important consideration is clearly the interpretability of the representations.

Although subjects exhibited little difficulty in arranging the stimuli into groups, articulation of the reasons for these judgements and labeling the groups proved more problematic. Nevertheless, grocery object **type** [A] appeared to be a much more important sorting criteria than was nature [A].

| solution | stress | RSQ   |
|----------|--------|-------|
| 1 D      | 0.346  | 0.695 |
| 2 D      | 0.148  | 0.906 |
| 3 D      | 0.078  | 0.965 |

Table 3. Measures of Fit for MDS Solutions (D= 1 to 3)

The 2D MDS solution (figure 1) was interpreted in terms of 4 distinct clusters; labeled '**animal products**', '**meals**', '**snacks and drinks**', and '**fruit & vegetables**'. The 3D MDS solution (figure 2) was interpreted in terms of the 3 continuous dimensions; labeled '**animal - plant**', '**solid- liquid**', and '**natural-processed**'.

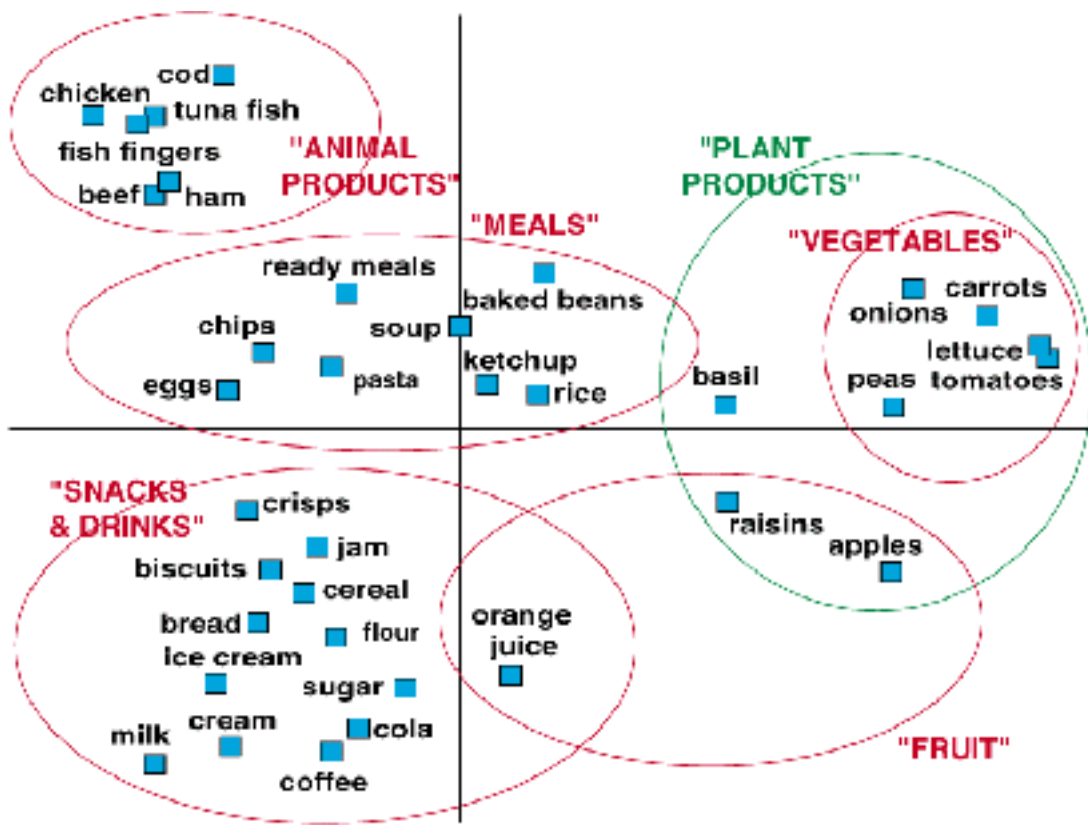


Figure 1. 2-Dimensional MDS Solutions

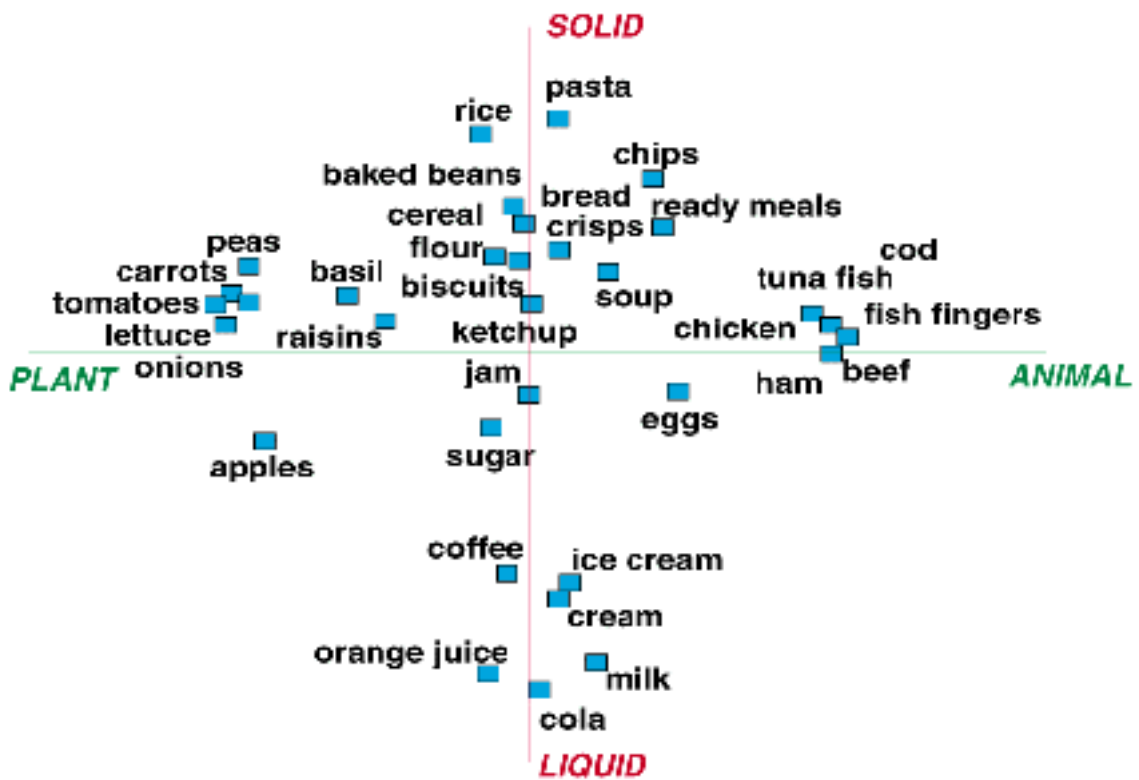


Figure 2. 3- Dimensional MDS Solutions

The dendrogram of the HCA solution (figure 3) was interpreted in terms of 5 principal clusters; labeled 'fruit and vegetables', 'animal products', 'liquids & sweets', 'staples', and 'meals and snacks'. Factor analysis of the similarity data supported a 5 cluster interpretation. These upper-level clusters could, however, be further decomposed; for example, the 'fruit and vegetables' cluster consists of distinct 'fruit' (apples and raisins) and 'vegetables' (lettuce, tomatoes, carrots and onions) subclusters.

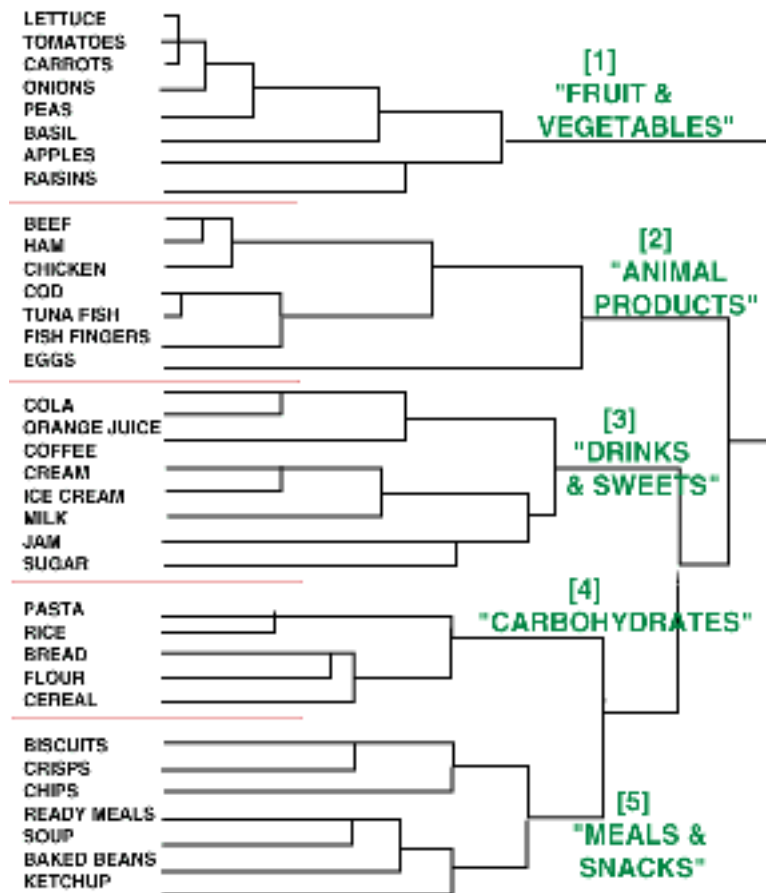


Figure 3. Hierarchical Clustering Solution

The good statistical fits of the MDS solutions suggests that a single 'group' solution provided an adequate representation of the structure of subjects' grocery object knowledge. Indeed, only one subject reported having employed idiosyncratic criteria of correspondence in their similarity judgments (i.e. "ones that I like/dislike").

## Discussion

The results of the cognitive mapping procedure were used to generate a set of user requirements for the organisation of grocery product information on the UI to an electronic database supporting grocery teleshopping. For example, people expect to find [frozen] fish fingers, [fresh] cod and [canned] tuna fish together. Extrapolation from the HCA solution suggests that grocery product information can be organised into 5 distinct categories, based on grocery object type [A]. The use of prototypical category exemplars as descriptors may also enhance category labeling (e.g. 'carrot' may be appended to the 'vegetables' category label) to facilitate information retrieval.

Although the nature [A] of grocery objects is an important determinant of their organisation in the supermarket worksystem, this is not reflected in the cognitive maps derived in the present study. Clearly, the organisation of groceries in a supermarket is affected by a host of worksystem constraints and marketing considerations which may not be relevant to a teleshopping environment. The supermarket metaphor may therefore not provide an appropriate structure for the organisation of grocery product information.

Although the application of cognitive mapping tools advances the problems of organising database information, some issues remain unresolved and need further interpretation. Thus highly differentiated grocery object categories - such as 'sauces' - remain difficult to classify and label. For example, 'chocolate sauce' and 'tomato ketchup', though of common type [A], are generally used in very different contexts. Indeed, when people are actually shopping, for example, the nature [A] of grocery objects may become a much more salient attribute than their type [A].

## Conclusion

Resolution of the methodological problems associated with the application of cognitive mapping techniques yields a set of tools which are potentially very valuable for informing design. Although the present study has been concerned with a specific instance of a teleshopping database, these tools are potentially applicable to a wide range of design problems in a variety of contexts. Their utility is likely to be enhanced through the use of more sophisticated elicitation and representational procedures (including 'framed-' and 'multi-' sorting; and Roske-Hostrand and Paap's (1986) Pathfinder algorithm).

The utility of cognitive mapping techniques, however, depends not only upon the extent to which they provide an accurate representation of subjects' cognitive structure, but also upon the extent to which cognitive compatibility itself facilitates information retrieval. Future research must attempt to assess the validity of cognitive maps through comparative evaluation of these taxonomies against those generated by expert opinion.

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