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Chapter 7

'Lost in Hyperspace': Cognitive Mapping and Navigation in a Hypertext Environment

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Abstract

This chapter describes an experiment which looks at how readers of a hypertext cognitively represent its structure. A database of information was formed into three different hypertext structures and presented to readers, who answered a series of questions about the information contained in the hypertext. The way the readers found the answers to the questions, and how they layed out a representation of the hypertext structure was recorded. Evidence gained from this data points to the formation of a spatial cognitive map by readers, which has implications for the structure of a hypertext and the types of navigation tools that should be provided.

Problems with Hypertext

Despite the great enthusiasm with which hypertext packages have been produced, there are still several problems to be overcome. According to Conklin (1987), one of the major problems of hypertext, and the one to which this paper addresses itself, is that of disorientation or 'getting lost' in a display network. Elm and Woods (1985) describe this situation as:

'The user not having a clear conception of the relationships within the system, or knowing his present location in the system relative to the display structure, and finding it difficult to decide where to look next within the system'.

They see this disorientation in terms of degradation of user performance rather than a subjective feeling of being 'lost', and define good spatial navigation skills as:

- The ability to generate specific routes as task demands require.
- The ability to traverse or generate new routes as skillfully as familiar ones.
- Orientation abilities, that is, the development of a concept of 'here' in relation to other places.

The first two items would be sufficient for a reader to navigate effectively through a hypertext. The third item may or may not be necessary, since all that is required to access a particular piece of information is the appropriate set of links to be actioned from the current location. However, perhaps users are attempting to create a comprehensive cognitive spatial map (a cognitive representation, similar in form to a street plan) of the data structure, complete with locations and routes, or perhaps they represent the environment by means of sequences of actions to each location. Mahony (1988) appears to support the spatial metaphor by suggesting that users would not be disoriented if they had a conceptual overview (or spatial representation) of the structure of the hypertext, stating that:

'The main disadvantages of using hypertext at present seem to be consequent of its sheer lack of physical presence and integrity the very flexibility of reading on screen is disorienting for a user who can't conceptualise an overview of the structure'.

In comparing hypertext with conventional linear text in book form, Conklin (1987) notes that any piece of text that the user wishes to locate in a book can only be further forward or further back from where they are currently located. He reminds us that hypertext, as well as providing us with more locations in which to store information and more dimensions in which to travel, also provides us with greater potential for becoming disoriented or lost. Clearly, locating text if the user doesn't know what is available or how to access it, it is a major problem. Jones (1987) points out that in many systems locating screens of information may not be possible without considerable knowledge of the hypertext structure and the user's current position within it. Again comparing hypertext with conventional linear text, Charney (1987) points out that the ordering of topics and points, and various traditional orienting devices such as overviews and summaries that are usually taken for granted in books and papers, are non-existent in hypertext, and thus the overall structure of the document is quite different.

These issues raise a number of questions. Is knowledge of the document's structure as important as Jones suggests? Is there any attempt to represent the structure of the document cognitively, and if so, what form does it take?

Cognitive Mapping

Several experiments have examined navigation and cognitive mapping in subjects experiencing a new, large-scale physical environment such as a town or city. The most notable of these was by Siegel and White (1975) who proposed a developmental sequence of cognitive representation whereby an individual's knowledge of the environment alters in form through a series of four stages, with each new form being superior to the last. They proposed that subjects initially recognised landmarks, these being objects that for some reason were prominent or notable in the environment, then formed route maps consisting of routes connecting the landmarks, followed by the creation of 'minimaps', which are survey-type maps of small areas, and finally developed full survey maps of the whole area by joining these minimaps together.

Many cognitive mapping studies have examined naturalistic environments, but others have used a simulated environment presented to subjects in the form of a series of slides, e.g. Cohen and Schuepfer (1980). Their study examined both route learning through a series of very similar corridors, and the formation of mental survey maps of the layout of the corridors. This form of presentation is very similar to the way in which screens of information in a hypertext database are presented. When subjects are required to access a particular piece of information in hypertext, the screens of data are analogous to rooms or landmarks, and the mouse clicks are analogous to traversing corridors between those screens. Canter, Rivers and Storrs (1985) have also considered the analogy between data navigation and physical environment navigation, stating that:

'It is fruitful to recognize the direct parallels between navigating concrete environments, such as cities or buildings, and navigating data. After all, such parallels are implicit in the navigation metaphor, so it is worth establishing whether or not there is a fruitful analogy between the psychological processes involved'.

There are two major advantages to having a survey-type cognitive map of any environment, be it a city or a database. Firstly, there is the opportunity to work out and utilize short-cuts to reach desired locations. Secondly, and probably most importantly, if the user/traveller is somehow distracted and/or becomes lost en route, there is a far greater chance that they can regain their bearings and reach their intended destination if they have a spatial cognitive map of the environment than if their knowledge is simply in route form.

Given the advantages of survey-type cognitive maps, and the analogy between navigating in a physical environment and in a hypertext, it seems plausible that the spatial cognitive representation of a hypertext would occur.

Experimental Rationale

In order to determine how individuals cognitively represent a database environment in the form of a hypertext document, an experiment was constructed that examined the effects of different hypertext structures on user's perceptions of the document. The hypertext document used for the purpose of the experiment was a specially constructed database containing information about various facilities offered by the City of Edinburgh and Edinburgh University in the form of a public information system. The information in the database was identical for all three conditions of the experiment, the only differences being in the underlying structures of the documents and consequently the methods of exploring the contents available to the subjects. The three conditions were:

HIERARCHY CONDITION

The hypertext document had a purely hierarchical structure and could only be explored by means of traversing the hierarchy. See Figure 1.

MIXED CONDITION

Again this had a hierarchical structure, but had additionally an alphabetical index containing the titles of every screen in the database. The index titles could be actioned to take the user to any screen directly and there was an index link at the foot of every screen in the database, making every screen accessible, via the index, from every other screen. Therefore, users could either traverse the hierarchy or use the index. See Figures 2 and 3.

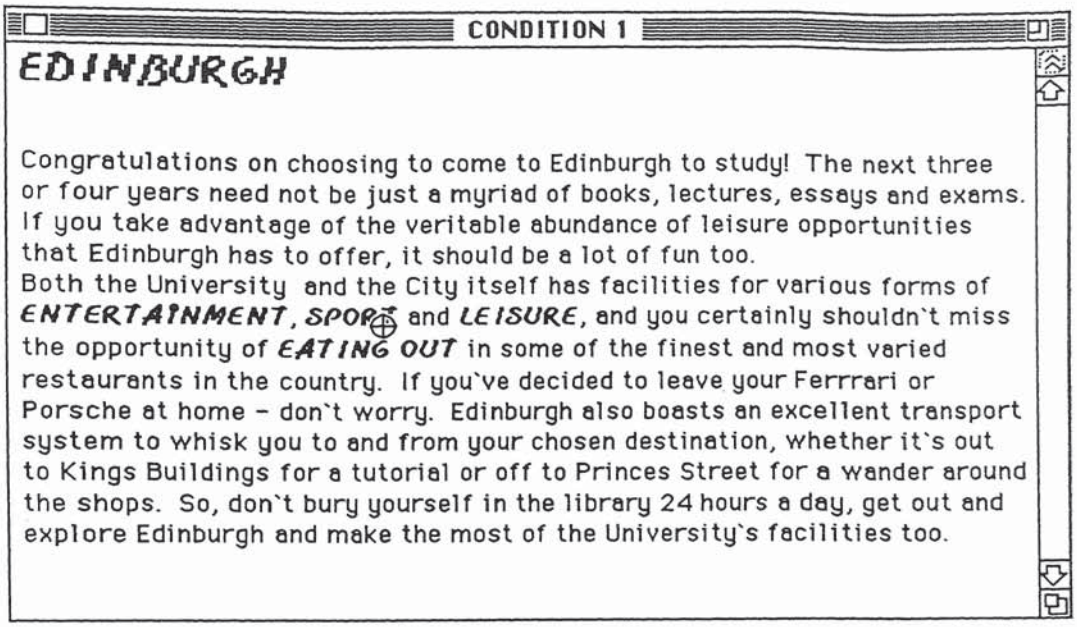

Figure 1. Top Level of Hierarchy Condition

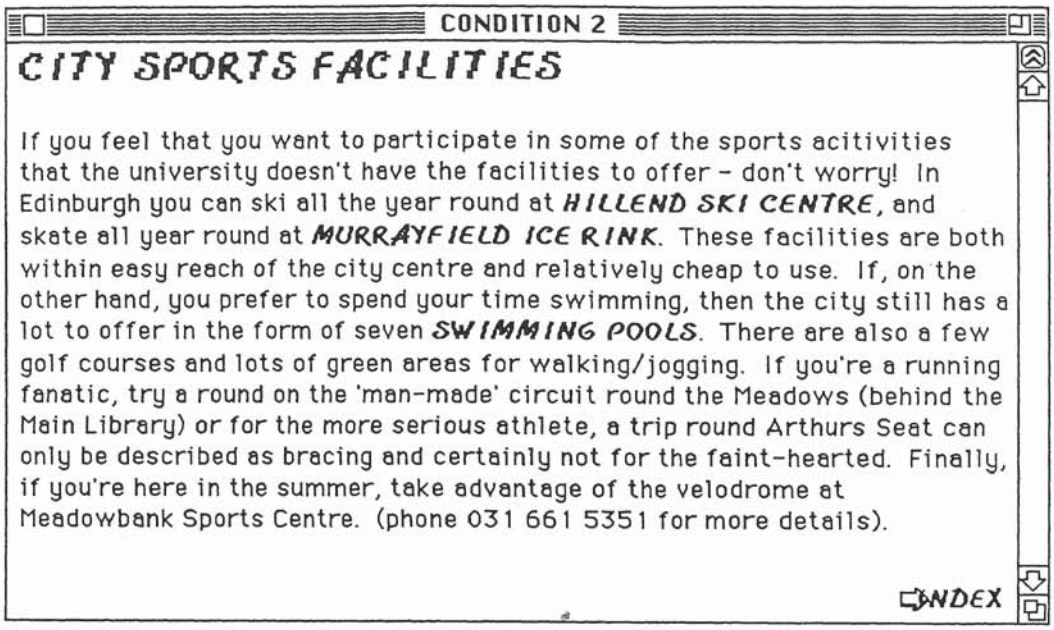

Figure 2 **Typical screen in Mixed and Index Conditions**

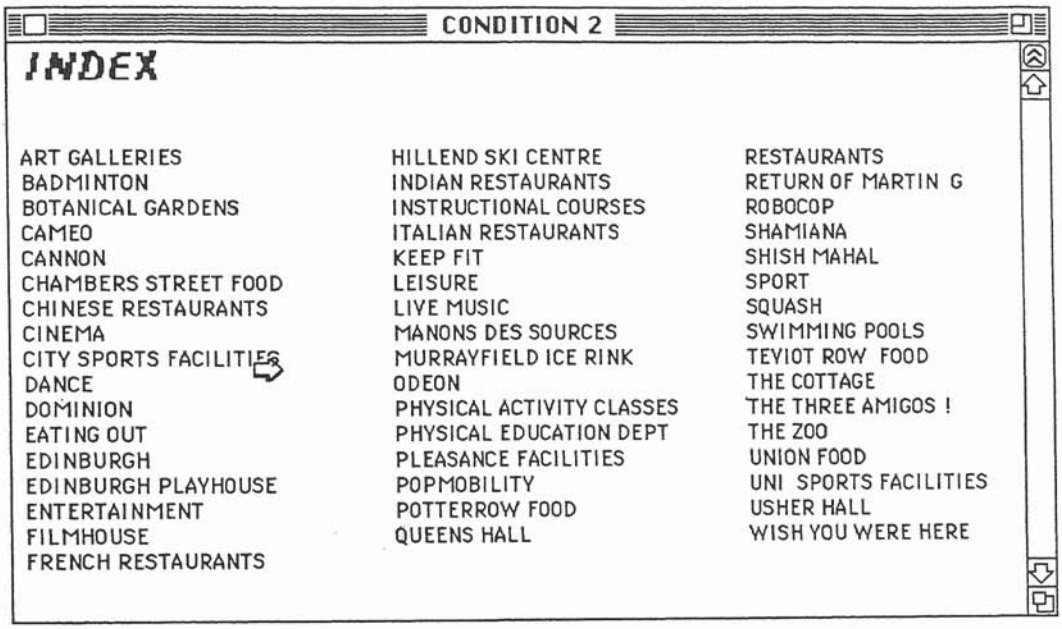

Figure 3 Index Screen

INDEX CONDITION

This form of the hypertext was simply the alphabetical index with no hierarchical structure at all. Thus, every screen was still immediately available from every other screen via the index, but any hierarchy that the subjects might perceive could not be directly traversed. The embedded titles of other screens were bold but not active. See Figures 2 and 3.

The bold items (other than the screen's title) are links to further screens of information.The bold items (other than the screen's title) are links to further screens of information in the Mixed Condition, but inactive in the Index Condition.

Each item (other than the screen's title) is a link to the appropriate screen in both the Mixed and Index Conditions.

In order that the subjects would have as similar a level of exposure to the hypertext document as possible, they were asked to perform a series of search tasks. Every odd numbered question was designed to be easier to answer by traversing the hierarchy, and every even numbered question by using the index, so, for example, a question easier to answer using the hierarchical structure would be 'Which cinema is showing the film "Roxanne"?' and one easier using the index structure 'Who are the main actors in the film "The Three Amigos"?'. This was done both to avoid one system being much easier than any other to use and also to promote a balanced mix of search strategy in the Mixed Condition.

The time taken per task and screens searched per task were recorded to give information on the efficiency of search and the mean time taken.

In an effort to determine any cognitive representation of the hypertext that the subjects might have, they were asked to perform a card-laying task. The subjects were asked to lay cards, with reduced versions of the screen on them, on a large board, as they imagined them to be arranged in the document, and also to draw any connecting computer links that they thought existed between these screens. This technique for determining the subject's knowledge of the data structure has previously been used by Parton *et al.* (1985).

A questionnaire was developed to examine other possible variables that might be responsible for any effects found, and also try to form some understanding of what was actually happening when subjects reported feeling 'lost'.

It was hypothesized that if the subjects were attempting to cognitively represent the data structure the users of the Mixed hypertext would have the process of cognitive map development, as proposed by Siegel and White (1975), disrupted. That is, as they tried to connect various areas together to form minimaps, or tried to connect minimaps together to form full survey maps, they would have difficulties in deciding where one minimap should be placed in relation to the others. This is because the index allows them to go directly to a section completely unrelated to a part of the hierarchy that has just been examined. Disruption would also occur because there are at least two potential models of the structure, the hierarchy and the index.

The value of the information about the structure of the hypertext varies between conditions. Knowledge of the structure is most valuable in the Hierarchy Condition, since it is the only means of navigating through the hypertext. Knowledge of the structure is least valuable in the Mixed Condition, since the required screen could be found using the hierarchical links or more directly via the index. Also, the compexity of the hypertext structure varies between conditions. The Index Condition structure is the most simple (the index screen is linked to every other screen), and the Mixed Condition structure is the most complex (both hierarchical and index structures are present).

It was expected that these differences between conditions would be evident in a variety of ways. Firstly the mean task performance times for subjects in the Mixed Condition would show a much slower improvement over time, that is subjects in the Hierarchy and Index Conditions would show a faster decrease in mean task time as their conceptually simpler systems would be much quicker to become familiar with.

Also, the Mixed hypertext would be less efficiently used than the others, that is the subjects would search a larger number of screens per question, because the subjects would have the least sophisticated representation of the structure (because knowledge of the structure is the least valuable and the most complex).

Further evidence for incomplete spatial cognitive representation was expected to be seen by the Mixed subjects' models being less spatial in nature (cards layed in groups of siblings) and more procedural in nature (cards laid 'parent-child, parent-child').

More direct evidence for the formation of the spatial cognitive map would be that subjects in the Hierarchy Condition would have the greatest knowledge of structure, again

determined from the card layout task, since they should have reached the most advanced stage of cognitive map development. Index Condition subjects would be expected to have good knowledge of the hypertext structure, as, despite being of little value for navigation, it has a very simple model.

The frequency of being 'lost', as reported via the questionnaire, was expected to be somewhat different for subjects in the Mixed Condition, as was the form of being 'lost'. The forms of being 'lost' that were looked at are as outlined by Elm and Woods (1985) :

- not knowing where to go next;
- knowing where to go, but not knowing how to get there;
- not knowing where they were in the overall structure of the document.

If subjects were creating spatial cognitive maps as suggested, and the Mixed subjects were experiencing difficulties with this, then it was hypothesized that they would experience being 'lost' more frequently and also that this would be most often in the form of 'not knowing where they were in the overall structure of the document'.

Method

The subject group recruited for this experiment consisted of 27 university undergraduates comprising 15 males and 12 females, with a mean age of 20.5 years, with little or no computing experience. Subjects were randomly allocated one of the three structures of the hypertext document, and their performance on each of the three parts of each condition - the search task, the card-sort and the questionnaire - was compared using a between-subjects design.

The experimental apparatus consisted of an Apple Macintosh micro computer, mouse and mouse pad. The hypertext documents used were produced using the software package Guide (produced by Office Workstations Limited), then converted to read-only documents using Guide Envelope.

Links, or buttons, in a document could be recognised in two ways. Firstly (for the purposes of this experiment) they appeared in bold type, and secondly the mouse cursor changed shape when moved over them. All buttons were actioned by the user clicking the mouse once.

The hypertext documents looked as similar as possible for all three conditions of the experiment, varying only in their structure and the availability of an index, as described earlier.

The subjects' interactions with the documents were recorded with a video camera to produce a time-stamped video-tape, of the computer screen and the subject's voice, for later analysis.

Fifty 9 cm x 5.5 cm cards, of the screens in the hypertext, were printed with the titles enlarged (for legibility), and were layed out on a 6' x 4' white board. Connections between the cards were drawn with a whiteboard dry-marker pen.

In the first part of the experiment subjects were shown the experimental hypertext document, after spending a small amount of time on a training document to familiarise themselves with moving around a hypertext. They were told they would be asked 20 questions, the answers to which could be found somewhere in the text of the document and they were asked to give their answers verbally. It was stressed that there were no trick questions, that the answers would always be explicitly expressed, and that even if the subjects happened to know the answer to a particular question, they should still attempt to find the screen with the appropriate information on it.

It was stressed that this was not a speed test, but that subjects should try to work through the tasks at a steady rate. The option of moving on to the next question was available if subjects felt that they could not find the answer to a particular question. Each question in turn was asked verbally, and a slip of paper with the question printed on it was placed nearby for reference.

This section of the experiment was video recorded, and a score was taken of the number of questions that the subject successfully managed to answer.

Secondly, subjects were taken to another part of the room and shown the white board with the cards arranged in random order on the right hand side. They were informed that these were all the screens of information that were available to them in the hypertext document, and that their task was to lay them out as they imagined them to be arranged in the hypertext document.

The whole screen, and not just the title, was used for each card, as some subjects may have been remembering the actual shape of the text or the screen layout. It was stressed that subjects should not read the small text on the cards, only the titles. This was

to avoid this part of the experiment becoming simply a deductive construction task. Before they attempted this task, the subjects were informed that after they had layed the cards out they would be asked to draw any connections that they thought existed between the cards. A score was then recorded of the amount of cards correctly placed. This was calculated by one mark being awarded for every card directly connected to its parent card. The way subjects layed out the cards was also categorised as being predominantly procedural, spatial or neither.

Finally, subjects were given the questionnaire to complete, and a copy of the question list to refer to.

Results and Discussion

VIDEO DATA

The number of questions correctly answered varied very little between the three conditions, with most subjects scoring over 80% correct.

The mean time per task was calculated for each subject, from which the mean task time per question for each condition was computed.

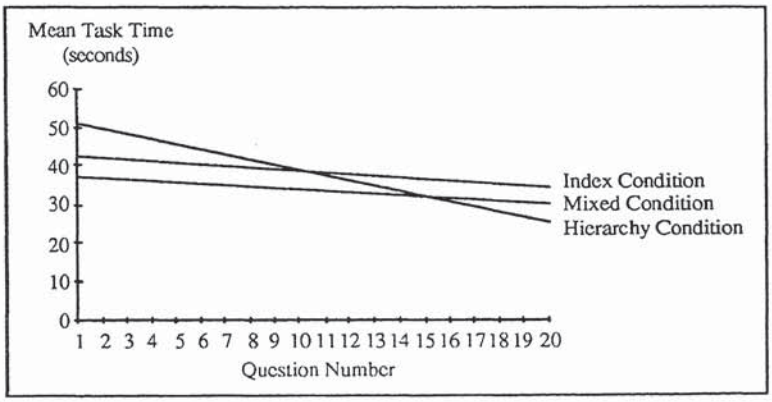

Table 1 : Regression graph of mean task time

As can be seen from the graph in Figure 4, there was a noticeable gradual decrease in the time per task for the Hierarchy Condition, while the time per task in the Mixed and Index Conditions remained relatively constant. (Note that the values of the mean task time cannot be compared since the minimum number of screens that needed to be searched per question in each condition were different.)

The mean number of screens searched per question were calculated for each subject, then combined to produce a mean for each of the three conditions. These were then compared with the minimum number of screens per question for each condition to produce a measure of efficiency of system use. A Kruskal-Wallis test on these measures revealed that the hypertext used most efficiently was the Index hypertext, and that used the least efficiently the Mixed hypertext ($H = 4.835$, d.f. $= 2$, $P < 0.1$).

Subjects in the Mixed Condition showed a slower decrease in mean task time than subjects in the Hierarchy Condition, suggesting that the Mixed hypertext was more difficult to 'get to know', although this also applies to the Index Condition. The Mixed hypertext was also found to be the least efficiently used. Taken together, these results suggest that there is something about the form of the Mixed hypertext that makes it inherently more difficult to use than the others. Perhaps this difficulty is a result of the continual disruption of attempts by subjects at forming survey-type cognitive maps of the hypertext.

Card Layout Data

HIERARCHY CONDITION

All of the layouts in the Hierarchy Condition had a hierarchical form, but varied in the directions in which they were layed. For example, most subjects placed the top level card 'EDINBURGH' at the top of the working area and had the tree progressing vertically down from it. Others were laid from left to right, with the top level at the left hand side. One subject laid the hierarchy in a 'sunburst' form, with the top level card in the centre of the board, and the branches of the tree radiating outward from it.

MIXED CONDITION

Most of the layouts by subjects in the Mixed Condition had a hierarchical form, although this varied between small sections, or 'minimaps', of hierarchy with the top card

only connected to the index card, and complete, largely accurate, hierarchies with subjects also realising the position of the index card in the structure (i.e. connected to every card). However, there was one subject who laid out a hierarchy but thought that the index was not connected to anything at all. Several layouts produced were in the form of an index. These were mainly laid in three alphabetically arranged columns, but subjects also demonstrated knowledge of some of the hierarchical connections between the cards, by drawing those in too.

INDEX CONDITION

The Index Condition produced as varied a range of layouts as the Mixed Condition. Several subjects layed out very accurate hierarchies and were also aware of the fact that the only connections that actually existed were the ones between the index and every card. When questioned about this, they informed the experimenter that they imagined the information to be arranged in a hierarchical form and considered using the index as merely a method of traversing this perceived hierarchy. One subject produced a layout that was a mixture of index and hierarchy, and another subject produced no layout at all, claiming that he had no idea at all of how the information was arranged. Perhaps a cognitive map was of so little value for this form of the hypertext that none was formed.

The layout forms on the whole conformed to expectations, which appears to support the hypothesis of the cognitive representation being at a more advanced 'spatial', survey-type stage for the systems with the simplest structures.

In the layout procedure, none of the layouts were purely procedural in nature. Most of the spatial layouts were produced in the Index Condition, and least spatial layouts were produced in the Mixed Condition. Most of the layouts in all conditions showed both spatial and procedural elements.

The spatial card laying usually occurred at the top of any hierarchy or piece of hierarchy that was laid, while the procedural laying tended to occur towards the bottom or leaf areas of hierarchy, or in areas that had either not been visited often or not been visited at all during the tasks. Thus, it would appear that subjects are attempting to 'place' each screen of information in relation to the other screens as they are encountered in some sort of cognitive representation, this representation for each card becoming more accurate and fixed with each encounter. This may support the developmental sequence proposed by Siegel & White (1975) for physical environments, with the representation progressing from landmark recognition, to procedural or route map form, then through minimap form, and finally to full survey map form. In which case it would then support the hypothesis that the difficulty for subjects in the Mixed Condition was the continual disruption of the

development of a cognitive representation. Alternatively the subjects may never get beyond the minimap form of representation, although subjects in the Hierarchy and Index Conditions appeared to have more developed cognitive models of the hypertext structure, which lends weight to the development hypothesis.

Further support was lent to the cognitive representation hypothesis by some of the layouts in the Index Condition. Several of the subjects in this condition arranged the cards in the form of a hierarchy, despite the fact that they could not directly traverse the hierarchy during the tasks (the hierarchy was visible in this condition, by the screen title buttons being in bold, but not active). The subjects commented that they were aware that screens were only accessible from the index, but that they imagined the data as having a hierarchical structure and simply used the index as a navigation tool to traverse this perceived hierarchy. Thus it was not necessary for subjects to directly traverse the hierarchy to perceive of hierarchical connections between the screens, suggesting perhaps that subjects were attempting to organise the data in some way.

The scores that each subject was given for their layout in the card-sort task, were compared using a Kruskal-Wallis test which showed significant differences in subjects' knowledge of structure between the three conditions. This knowledge was greatest for Hierarchy, then for Index, and least for Mixed ($H = 8.66$, d.f. $= 2$, $p < 0.02$). This knowledge of the structure supports the hypothesis that subjects in the Hierarchy and Index Conditions would have the greatest knowledge and those in Mixed the least. It suggests again that there is difficulty in acquiring a conceptual model of the structure of the hypertext document in Mixed.

Questionnaire Data

The subjects' responses to questions in the questionnaire were analysed, using Kruskal-Wallis tests, to determine if there were significant differences between conditions in the ratings given to:

- Satisfaction of interaction
- Clarity of information within the document
- Understanding of how to use the computer
- Difficulty of the tasks.

'Satisfaction of interaction' was found to be significantly different between the conditions, with the subjects in the Hierarchy Condition reporting most satisfaction. The

Mixed Condition received the second lowest rating, with its mean rating being marginally above that of Index, which was reported to be the least satisfying to use ($H = 5.78$, d.f. = 2, $p < 0.1$). There were no significant differences found between the conditions for ratings given to the other three items.

This highest 'Satisfaction of Interaction' rating was for the Hierarchy Condition is possibly because the data conformed to a structure that was relatively easy to conceptualise in terms of chunks or minimaps. The middle satisfaction rating was given to the Mixed Condition. If cognitive representation is occurring, then the Mixed hypertext is probably not very satisfying to use because it is difficult to connect any areas of data together to produce a view of the overall structure of the document. Quite surprisingly, the Index hypertext received the lowest satisfaction rating, although this was only fractionally lower than the rating given to Mixed. This was possibly because the apparent attempts at organisation, seen in the card layouts produced by subjects in the Index Condition, were much more difficult, as the hierarchy could be seen but not directly traversed, thereby causing the system to be somewhat frustrating to use.

Subjects were also asked which questions they found to be especially difficult. The proportion of subjects in each condition that reported at least one such task were Hierarchy 50%, Mixed 80%, Index 60%. The reasons given for tasks being difficult were usually along the lines of the information not being where the subjects expected it to be, or the subject not being able to decide where to search for the information.

In answers to other questions, several subjects in each condition reported feeling 'lost' while doing the tasks. The proportions of subjects in each condition reporting this were Hierarchy 30%, Mixed 70%, Index 50%. While this shows that more of the subjects in the Mixed Condition expressed feeling 'lost' this result was not significant (Chi-Square test with c2 = 3.2, d.f. = 2).

The form of loss reported by subjects also varied between the conditions, and had the profile shown in Table 2

Form of being 'lost'	Hierarchy Condition	Mixed Condition	Index Condition
Not knowing where to go next.	2	7	3
Knowing where to go, but not knowing how to get there.	-	3	-
Not knowing where they were in relation to the overall structure of the document.	1	4	1

Table 2: Form of being 'lost' reported

As can be seen from Table 2, in the Mixed Condition more subjects reported each form of loss than subjects in any of the other conditions. Additionally, these subjects were the only ones to express feeling the form of being lost where they 'knew where to go but didn't know how to get there'. Finally, they also reported a feeling of "not knowing where they were in relation to the overall structure of the document' than subjects in either of the other two conditions.

The particular questions found to be especially difficult for subjects in each condition also lend support to the cognitive mapping hypothesis. Question 4 'Where are the dance classes held?' was frequently found to be reported as difficult by subjects in the Hierarchy Condition. This could have been for two reasons. Firstly, the question involved the first search of the deepest branch of the hierarchy and thus subjects were encountering a great deal of new 'territory' which would perhaps have to be incorporated into the current conceptual model. Secondly, the screen to be found, DANCE, was actually within the category of SPORT, but could equally have been in ENTERTAINMENT or LEISURE. Thus the general area in which the answer could be found was not obvious, and possibly did not conform to the expectations of the subjects. This emphasizes the problems of categorizing hierarchical structures and also illustrates the influence that hierarchical categories have on users' conceptual models and their expectations of the probable contents of those categories.

The question most difficult for Index subjects was number 17 - What is a Kakori Kebab made from ?. This was most likely not found difficult by subjects in the Hierarchy Condition as they had the support of the hierarchy. That is, knowing that a kebab is an

item of food, they could search within the area of EATING OUT. However, subjects in the Index Condition could only look at index items that might be related to food without knowing the contents and boundaries of the appropriate section, or try to find this information by laboriously traversing the perceived hierarchy via the index.

More subjects in the Mixed Condition found at least one of the tasks especially difficult, although no particular question stood out as being especially difficult. Given that the subjects had both search methods available, this could have been the result of difficulties in choosing which strategy to use, or general distress at being unable to form a cognitive map of the structure causing a degradation in user performance.

Correlational Measures

The following correlational measures were computed from the data using the Spearman Rank Correlation Coefficient.

Knowledge of structure was positively correlated with the reporting of feeling lost, i.e. those with least knowledge of the overall structure of the document were also those who most often expressed feeling lost. The result was a positive correlation between the two measures,with $r = 0.488$, which was significant at the $P < 0.01$ level for a one-tailed test.

Knowledge of structure was also positively correlated with the satisfaction rating given to the system used ($r = 0.33$, $P < 0.05$ for a one-tailed test). Thus, it appears that some of the satisfaction expressed by users is related to the amount they knew about how the information was arranged.

The correlation between satisfaction rating and being lost (in all forms) also suggests that knowledge of the arrangement of the information and of the user's current position within it was an important factor for the individuals using this system ($r = 0.467$, $P< 0.01$ for a one-tailed test). Therefore, the subjects giving their interaction with the document the lowest ratings also most often reported being 'lost'.

Conclusions

The subject population was atypical, in that it consisted of university undergraduates in their early twenties, which would present difficulties when trying to extend the results to make predictions about the behaviour of the general population.

Refinements of this study could be made to the classification of the form of the layout in the card-layout task. The layouts were classified by the experimenter, who was aware of which hypertext structure the subject had been exposed to.

The database used for this experiment consisted of items that were 'naturally' hierarchically organised, that is most individuals would classify the data in this way themselves, e.g. ODEON, CANNON and DOMINION coming under the heading of CINEMA. This was done to make the experiment as naturalistic as possible, as information systems encountered by the general public would probably have this type of 'natural' hierarchy. A further experiment could be designed to look at what would happen when using a database of, for example, nonsense syllables.

The subjects in this study who used the Mixed hypertext frequently used the index available in the following way. Firstly they would access a general area of the document, e.g. cinema, which they would then explore using the hierarchy. The index was only used to access a specific screen directly if the user had difficulties in finding it using the other method, or had reached a later stage in the tasks, suggesting that they were more familiar with the document.

The finding of this paper, that individuals appear to be attempting to create cognitive representations of hypertext structures in the form of a survey-type map, and the difficulties of doing so for users of a mixed structure hypertext, has implications for the way hypertext documents are structured and for the types of orienting or navigation devices available to hypertext readers.

Readers should be allowed to develop a cognitive map of one view of the data structure before being given the option of navigating through the data some other way. This could be implemented in two ways. Firstly, readers could be advised only to use one search method until they felt quite familiar with the data structure. Secondly, the document could have two types of index available, where one is a contents screen (similar to that normally found in text books), and another reflects more directly the 'minimap' representation readers are likely to develop, for example an index of main sections linked to their own more detailed contents.

The most appropriate types of navigation devices would be those that are spatially-based, i.e. present the information structure in a 2 or 3-dimensional form, rather than those which simply keep account of the names of the screens that the user has viewed, although Conklin (1987) has demonstrated the difficulties that occur, using a 2-dimensional representation, when the number of links between data items become extensive.

A spatially-based navigation device has been used very effectively by Tom Hewett (1987) in The Drexel Disk. This is a form of electronic 'guidebook' which runs on the Macintosh personal computer, and is given to freshmen entering Drexel University in Philadelphia. The Drexel Disk uses graphics to present spatial information, and also provides recall cues to help locate and retrieve information. Given the findings of this study, and the fact that the Drexel students reported that they liked the overall organization of their Disk, perhaps we should look towards methods normally used for making physical environments more memorable and navigable, and apply these to help prevent users becoming 'lost in hyperspace'.

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