Navigation in hyperspace: An evaluation of the effects of navigational tools and subject matter expertise on browsing and information retrieval in hypertext

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Abstract

This study examined the effectiveness of a map and a textual contents list on the navigation performance of subjects with and without prior knowledge of the text topic. After reading the text, subjects used the document to answer ten questions. The results showed that performance in the map condition was superior to that of the contents list condition, which in turn was superior to that of the hypertext only condition (no navigational aid). In addition, knowledgeable subjects performed better than non-knowledgeable subjects, except in the map condition where their performance was equivalent. The results also show that non-knowledgeable users tend to rely more heavily on navigational aids than knowledgeable users, and that aids were used primarily during browsing. These results are discussed in relation to the ways in which navigational aids interact with the prior knowledge of the user to enhance or impede performance. © 1998 Elsevier Science B.V.

Keywords: Hypertext; Disorientation; Information retrieval; Navigation; Navigational aids; Browsing

The use of hypertext for information retrieval is not without its associated problems. Research suggests that both non-knowledgeable and knowledgeable users already familiar with the subject domain of the text, are unable to explore hypertext without experiencing disorientation [1]. In response to such disorientation a number of navigational aids have been developed. However, empirical evidence for the utility of such aids is less than clear cut. The aim of this paper is to evaluate the effectiveness of two common navigational aids, localised spatial maps and a textual contents list, on the navigation performance of subjects with and without prior knowledge of the text topic.
1. Disorientation

The problem of disorientation in hypertext generally results in a measurable decline in user performance [2]. Typically, the disorientated user is unable to gain an overview of the material, encounters problems in deciding if needed information is available, and problems in deciding where to look for the information, and how to get there [3,4].

Disorientation while browsing can lead the browser to miss out sections of the text and to open the same few nodes repeatedly [5]. For this reason we measured the number of different cards opened and the number of cards opened more than once during browsing. The effects of disorientation on navigation, can increase the time users take to locate information, and lead them to follow less than optimal routes through the hypertext [6], and cause them to experience problems in formulating a search request [7]. Therefore, we measured the time it took users to retrieve information and the directness of their route to that information.

2. Navigational aids

In order to minimise some of the negative effects of disorientation, a number of navigational aids have been developed. These aids work by allowing users to review and preview their progress through hypertext. Research has shown that hypertext users can and do make use of a variety of navigational aids [8]. They report the findings of an exploratory study which examined the use and effectiveness of navigational tools in hypertext. The tools studied were guided tours, an index and a map. Their subjects made extensive use of the tools, and reported that they found them easy to use. In addition, subjects used the tools strategically, in a task directed manner. For example, the map was commonly used during browsing, and the study of partially familiar material, whereas the index was used more often during information search. However, Edwards and Hardman [3] and Gupta and Gramopadhye [9] warn that hypertext designers should guard against providing too many navigational tools within the same system. They suggest that providing an array of navigational tools can confuse the user due to the mismatch between the actual hypertext structure and the structural information provided by the tools. For example, an index may not highlight the links between nodes whereas a map would make these relationships explicit.

We will now look at some of the more popular navigational tools in more detail and present the research data on the effectiveness of these aids in helping to relieve user disorientation. In particular we will focus on the use of textual aids such as contents lists and spatially based aids such as maps.

3. Indices and contents listings

Indices and contents lists are commonly used in traditional text as a means of assisting users to gain an overview of the breadth of material covered in the document, and to find
specific information within the text. Both of these aids are also used as a means of assisting hypertext users in their search for information. Indeed, studies conducted by Dee-Lucas and Larkin [10] have demonstrated the usefulness of providing hypertext users with indices and contents lists. Dee-Lucas and Larkin [10] found that the provision of a contents list improves both navigation and memory for text topics.

4. Spatial maps

The spatial map or graphical browser presents an overview of the structure of the hypertext in the form of a diagrammatic representation of the hypertext nodes and the links which connect them. This pictorial representation tackles the problem of disorientation by allowing users to gain an understanding of the relationships that lie within the system, and by helping them gain a sense of their own location relative to other parts of the hypertext.

However, the effectiveness of maps as navigational aids may interact with factors such as document size [9]. Hypertext systems may contain hundreds, if not thousands of nodes with a myriad of links between them. Clearly, documents of this size would not lend themselves easily to diagrammatic representation, and even if they did, limitations of screen size would not permit them to be displayed simultaneously. Moreover, there is the ever present danger that users would find such complex data structures confusing rather than helpful. One way to minimise the complexity of spatial maps is to provide users with a series of localised or fisheye maps that are specific to the area of the hypertext document they are in at any one time, as opposed to one global frame of reference.

The empirical evidence regarding the effectiveness of maps as navigational aids in hypertext is less than clear cut. Studies conducted by Monk et al. [11] and Simpson and McKnight [5] have found that maps can lead to more efficient navigation behaviour. For example, Monk et al. [11] showed that the provision of a non-interactive map improved readers’ ability to use hypertext for problem solving. In a similar vein, Simpson and McKnight [5] found that subjects who had access to a graphical contents list showing the relationships between various parts of the text were more efficient in their use of hypertext in terms of the accuracy of their route through the document, and were better able to represent the document’s structure as a cognitive map than subjects who had access to an alphabetical index. Chen and Rada [12], Chen et al. [13], and Sarkar and Brown [14] also suggest that fisheye maps or browsers facilitate information seeking in hypertext environments. Moreover, Allinson and Hammond [8], Dee-Lucas and Larkin [10], and Wenger and Payne [15] have shown that the inclusion of a map also increased the amount of material reviewed during browsing, and decreased the number of nodes repeatedly opened. Taken together, these findings seem to suggest that a graphical representation may help users overcome some of the problems typically associated with disorientation. By contrast, Stanton et al. [16] found that the inclusion of a map resulted in poor performance of a sentence completion task, less use of the system in terms of following secondary links and lower perceived control over the system.
5. Aims

What the studies described above fail to show is how these navigational tools interact with the prior knowledge of the user. Hammond [17] suggests that disorientation may be heightened for subjects who are unfamiliar with the knowledge domain of the text. Indeed, Shin et al. [18] and McDonald and Stevenson [1] have shown that subjects who lack sufficient prior knowledge of the text topic demonstrate more navigational problems than subjects with high prior knowledge. It seems likely, for example, that experts have fewer navigation problems in hypertext because their grasp of the conceptual structure of the subject matter imposes structure on the hypertext. Therefore, it is necessary to examine which tools may help novices overcome the lack of such conceptual support. The aim of this study is to examine the effects of two navigational aids, a textual contents list and a spatial map, on navigation performance in non-linear hypertext. The study also seeks to examine the relationship between navigational aids and domain expertise. It is predicted that the performance of knowledgeable subjects will be superior to that of non-knowledgeable subjects and that subjects in the map condition will demonstrate superior browsing and navigation performance.

6. Method

6.1. Subjects

Thirty six student volunteers from Durham University served as subjects. Half of the subjects were knowledgeable about the subject matter of the text (psychology postgraduate students), the other half were non-knowledgeable (first year undergraduates from other disciplines). All subjects had equivalent computer experience. Subjects were tested individually.

6.2. Materials

The hypertext document used in the experiment is called 'The Nature of Human Learning'. This text is approximately 4500 words in length and was taken from Refs. [19,20]. The text was adapted for use in hypertext format by the present authors. The nodes in the hypertext document were linked to form a network based on a number of cross referential links. A link was established via keywords or text buttons in the text of each node, to other related nodes. Subjects moved through the hypertext by clicking on text buttons (highlighted keywords). The document also included a backtrack facility. The hypertext documents were implemented using HyperCard 2.2. The test document consisted of 45 individual nodes. Three hypertext conditions were used (map, contents list and basic hypertext). In the map condition subjects were provided with localised spatial maps of the document (see Fig. 1 for an example). In the contents list condition subjects were provided with a scrollable contents list of all of the nodes in the hypertext. In the basic hypertext condition, no navigational aid was provided. The navigational tools were non-interactive because it was considered that if subjects had to traverse the links
within the text, they would gain a greater understanding of its structure than if they were able to select destination nodes directly from the navigational aids. The aids were displayed in a separate window from the main text. Subjects' movements were monitored unobtrusively by the use of a tracking program which recorded the nodes visited during reading and question answering, the time it took subjects to answer the questions, and the number of times the navigational aids were accessed.

6.3. Design

The experiment used a between subjects design. The independent variables were navigational aid (map, contents list, raw hypertext), and prior knowledge. The dependent variables were: the number of different nodes opened during reading, the number of repeated nodes opened during reading (measures of reading); the number of questions correctly answered, the mean number of additional nodes accessed per question (the shortest route to reach each answer was determined. This figure was subtracted from the actual number of nodes opened to give an additional node score); the time taken to locate the answers (measures of navigation); and the number of times each navigational tool was used during reading and question answering.

6.4. Procedure

After reading a computerised tutorial which explained how to use the hypertext document, subjects were instructed to read through the hypertext until they thought they had seen the whole document, using the navigational aid (if present) as necessary.
The number of different nodes opened during reading, the number of repeated nodes visited excluding backtracks, and the number of times the navigational tools were used were recorded. Subjects then used the document to answer 10 questions. The answers to the questions could be found in specific nodes in the document. Subjects were instructed to navigate through the hypertext document to locate the answers, taking the most direct route through the text, using the navigational aid (if present) as necessary.

The presentation order for the ten questions was randomised for each subject. The number of nodes opened over and above the minimum needed to locate each answer, the time taken to find the answers, the accuracy of the subjects’ responses, and the number of times the navigational tools were used was recorded. Finally, subjects completed a post test questionnaire examining user disorientation.

7. Results

7.1. Reading

7.1.1. Number of different nodes opened

The first row of Table 1 presents the mean number of different nodes opened during reading, for all three subject groups, for both non-knowledgeable and knowledgeable subjects.

A between subjects ANOVA revealed two significant main effects: aid (F(2,30) = 60.0, p < 0.001), and prior knowledge (F(1,30) = 11.2, p < 0.001). Tukey HSD tests indicated significant differences between all three subject groups (hypertext vs. contents list: Q(3,30) = 7.6, p < 0.01; hypertext vs. map: Q(3,30) = 15.5, p < 0.01; contents list vs. map: Q(3,30) = 7.9, p < 0.01). Subjects in the map condition opened significantly more nodes during reading than subjects in the contents list condition, who in turn, opened more nodes than subjects in the hypertext condition. The main effect of prior knowledge arose because knowledgeable subjects (mean = 31.5) opened more nodes than non-knowledgeable subjects (mean = 26.1). There was no interaction between aid and prior knowledge.

7.1.2. Number of repeated nodes

The second row of Table 1 presents the mean number of repeated nodes opened for all three hypertext conditions, for both non-knowledgeable and knowledgeable subjects. A

<table>
<thead>
<tr>
<th></th>
<th>Hypertext</th>
<th>Contents list</th>
<th>Map</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>K</td>
<td>NK</td>
<td>K</td>
</tr>
<tr>
<td>Different nodes</td>
<td>21.3</td>
<td>15.3</td>
<td>32.7</td>
</tr>
<tr>
<td>Repeated nodes</td>
<td>5.5</td>
<td>6.8</td>
<td>4.3</td>
</tr>
</tbody>
</table>

K = Knowledgeable; NK = Non-knowledgeable.
between subjects ANOVA revealed two significant main effects: aid \(F(2,30) = 17.6, p < 0.001\), and prior knowledge \(F(1,30) = 6.3, p < 0.001\). Tukey HSD tests indicated significant differences between the map condition and the other two conditions only (hypertext vs. map: \(Q(3,30) = 8.1, p < 0.01\); contents list vs. map: \(Q(3,30) = 5.9, p < 0.01\); hypertext vs. contents list: \(Q(3,30) p < 1\)). Subjects in the map condition opened significantly fewer repeated nodes during reading than subjects in the other two conditions. The main effect of prior knowledge arose because knowledgeable subjects (mean = 4.1) opened fewer repeated nodes than non-knowledgeable subjects (mean = 5.3). There was no interaction between aid and prior knowledge.

7.2. Navigation

7.2.1. Correct answers

The number of correct answers was recorded for each subject, these are shown in Fig. 2. A between subjects ANOVA revealed significant main effects of: aid \(F(2,30) = 19.7, p < 0.01\), and prior knowledge \(F(1,30) = 35.3, p < 0.01\). There were fewer correct answers in the hypertext condition than in the other two conditions. Knowledgeable subjects answered more questions correctly (mean = 9.9) than non-knowledgeable subjects (mean = 8.3).

There was also a significant interaction between aid and prior knowledge \(F(2,30) = 13.3, p < 0.01\). Tests of simple effects revealed that knowledgeable subjects performed better than non-knowledgeable subjects in the hypertext and contents list conditions, but not in the map condition (hypertext: \(F(1,30) = 55.6, p < 0.01\); contents list: \(F(1,30) = 6.2, p < 0.02\); map: \(F(1,30) = 55.6, p < 1\)). There was also a significant effect of aid for non-knowledgeable

![Fig. 2. Mean number of questions correctly answered as a function of prior knowledge and navigational aid.](image-url)
Non-knowledgeable subjects performed better in the map and contents list condition than in the hypertext condition (hypertext vs. map: $Q(2,30) = 11.04, p < 0.01$; hypertext vs. contents list: $Q(2,30) = 8.03, p < 0.01$). However, there was no difference between non-knowledgeable subjects in the map and contents list condition (contents list vs. map: $Q(2,30) = 3.01, ns$).

### 7.2.2. Time taken

The mean time to answer the ten questions was calculated for each subject. These means are shown in Fig. 3. A between subjects ANOVA revealed a main effect of aid ($F(2,30) = 24.9, p < 0.001$), and prior knowledge ($F(1,30) = 20.5, p < 0.001$). Times were fastest with the map, next fastest with the contents list and slowest with the basic hypertext. Knowledgeable subjects (mean = 93.8) found the answers faster than non-knowledgeable subjects (mean = 113.6).

There was also a significant interaction between aid and prior knowledge ($F(2,30) = 3.9, p < 0.02$). Tests of simple main effects revealed that knowledgeable subjects performed better than non-knowledgeable subjects in the hypertext and contents lists condition but not in the map condition (hypertext: $F(1,30) = 15.7, p < 0.01$; contents list: $F(1,30) = 12.5, p < 0.01$; map: $F(1,30) = 0.8, ns$). They also revealed that there was a significant effect of aid for both non-knowledgeable and knowledgeable subjects (non-knowledgeable: $F(2,30) = 24.1, p < 0.001$; knowledgeable: $F(2,30) = 5.0, p < 0.01$).

![Fig. 3. Mean time taken to answer questions as a function of prior knowledge and navigational aid.](image)
Non-knowledgeable subjects found the answers fastest in the map condition, next fastest in the contents list condition, and slowest in the hypertext condition (hypertext vs. map: $Q(2,30) = 9.6, p < 0.01$; hypertext vs. contents list: $Q(2,30) = 3.2, p < 0.01$; contents list vs. map: $Q(2,30) = 6.4, p < 0.01$). Knowledgeable subjects in the map condition found the answers faster than subjects in the hypertext condition (hypertext vs. map: $Q(2,30) = 4.5, p < 0.01$). The contents list condition fell between these two extremes and was not significantly different from the map condition ($Q(2,30) = 1.9, \text{ns}$) or the hypertext condition ($Q(2,30) = 2.5, \text{ns}$).

### 7.2.3. Additional nodes

The mean number of additional nodes opened to find each answer was calculated for each subject. These means are shown in Fig. 4. A between subjects ANOVA revealed significant main effects of: aid ($F(2,30) = 50.3, p < 0.01$), and prior knowledge ($F(1,30) = 23.3, p < 0.01$).

Tukey HSD tests revealed a significant difference between all three subject groups (map vs. hypertext: $Q(3,30) = 14.1, p < 0.01$; map vs. contents list: $Q(3,30) = 8.1, p < 0.01$; contents list vs. hypertext: $Q(3,30) = 6.0, p < 0.01$). Subjects in the map condition opened fewer additional nodes than subjects in the contents list condition, who in turn, opened fewer additional nodes than subjects in the hypertext condition. Knowledgeable subjects (mean = 5.4) opened fewer additional nodes than non-knowledgeable (mean = 7.7).

![Fig. 4. Mean number of additional cards opened during question answering as a function of prior knowledge and navigational aid.](image-url)
There was also a significant interaction \((F(2,30) = 4.2, p < 0.02)\). Tests of simple effects revealed that knowledgeable subjects performed better than non-knowledgeable subjects in the hypertext and contents list condition but not in the map condition (hypertext: \(F(1,30) = 19.4, p < 0.01\); contents list: \(F(1,30) = 12.1, p < 0.01\); map: \(F(1,30) = p < 1\)).

7.2.4. Use of the navigational aid

The number of times subjects used the navigational tools during reading and information retrieval were recorded. Table 2 presents the mean number of times each aid was used during reading and information retrieval by both non-knowledgeable and knowledgeable subjects.

A three factor repeated measures ANOVA revealed significant main effects of aid \((F(1,20) = 19.3, p < 0.01)\), prior knowledge \((F(1,20) = 157.2, p < 0.01)\), and task type browsing or information retrieval \((F(1,20) = 10.8, p < 0.01)\). The main effect of aid arose because subjects in the map condition used their aid more times (mean = 11.2) than subjects in the contents list condition (mean = 9.4). The main effect of prior knowledge arose because non-knowledgeable subjects accessed the aids more times (mean = 12.8) than knowledgeable subjects (mean = 7.8). The main effect of task type arose because subjects used the aids more times during browsing (mean = 11.5) than information retrieval (mean = 9.1).

However, there was also a significant interaction between aid and prior knowledge \((F(1,20) = 6.3, p < 0.02)\). This interaction modified the main effect of aid. Non-knowledgeable subjects used the map significantly more times than the contents list \((F(1,20) = 23.8, p < 0.01)\). However, there was no difference between the number of times knowledgeable subjects used the map and contents list \((F(1,20) = 1.7, \text{ns})\). The three-way interaction between aid, prior knowledge and text type was not significant.

7.2.5. Questionnaire data

The questionnaire consisted of ten items, half positive and half negative in tone. A typical negative item on the disorientation scale was; ‘‘When using the document I often had a feeling of being lost’’. The questionnaire was scored in the following way. Under each item a five point scale was presented, ranging from strongly agree, to strongly disagree. Subjects circled the response they wished to make. Five points were awarded for strongly agreeing with a negative statement, and one point for strongly disagreeing with a negative statement. The scale was reversed for positive items. Table 3 presents the total scores per condition for the disorientation scale. The higher the score the greater the perceived disorientation.

Table 2

<table>
<thead>
<tr>
<th>Knowledgeable</th>
<th>Non-knowledgeable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Browsing</td>
<td>Information retrieval</td>
</tr>
<tr>
<td>Spatial map</td>
<td>9.8</td>
</tr>
<tr>
<td>Contents list</td>
<td>8.7</td>
</tr>
</tbody>
</table>
Table 3  
Mean scores for the disorientation questionnaire  

<table>
<thead>
<tr>
<th></th>
<th>Hypertext</th>
<th>Contents list</th>
<th>Spatial map</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disorientation</td>
<td>K</td>
<td>NK</td>
<td>K</td>
</tr>
<tr>
<td>score</td>
<td>37.5</td>
<td>42.5</td>
<td>26.0</td>
</tr>
</tbody>
</table>

K = Knowledgeable; NK = Non-knowledgeable.

A between subjects ANOVA revealed significant main effects of aid ($F(2,30) = 29.4, p < 0.001$) and prior knowledge ($F(1,30) = 23.1, p < 0.001$). Tukey HSD tests indicated significant differences between all three subject groups (hypertext vs. contents list: $Q(2,30) = 5.9, p < 0.01$; hypertext vs. map: $Q(2,30) = 10.8, p < 0.01$; contents list vs. map: $Q(2,30) = 4.9, p < 0.01$). Subjects in the map condition reported fewer feelings of disorientation than subjects in the contents list condition, who in turn, expressed fewer feelings of disorientation than subjects in the hypertext condition. Knowledgeable subjects reported fewer feelings of disorientation (mean score = 28.3), than non-knowledgeable subjects (mean score = 36.1).

8. Discussion

These results indicate that in general, both knowledgeable and non-knowledgeable subjects benefit from navigational aids, a map being more beneficial than a contents list. These findings are in line with those of Monk et al. [11] and Simpson and McKnight [5]. Subjects also make strategic use of these aids. In the main, they use them most when browsing, and non-knowledgeable subjects use them more often than knowledgeable subjects, particularly the map. These results are consistent with the idea that knowledgeable subjects could use their background knowledge of the subject domain to guide their explorations. They also lend support to Allinson and Hammond [8] and Dee-Lucas and Larkin [10] who suggest that maps are most useful when gaining familiarity with new material.

As regards navigational performance, the most striking finding is that the use of a map eliminated the differences between knowledgeable and non-knowledgeable subjects on all three measures, the time taken to answer the questions, the number of questions correctly answered, and the number of additional cards opened. Thus, once they had familiarised themselves with the material during reading, non-knowledgeable subjects found the answers as easily as knowledgeable subjects as long as they could use a map. There are two possible reasons for this facilitation. One is that the maps simply laid bare the structure of the document. The other, and the one we think the most plausible, is that the localised maps reflected aspects of the conceptual structure of the document. For example, one localised map showed the structure of the material that discussed problem solving, another showed the structure of the material that discussed memorising, and a third showed the structure of the material that discussed understanding. Thus the spatial structure reflected the conceptual structure.
The spatial structure also aided the knowledgeable subjects, but to a lesser extent. This is what we would expect if knowledgeable subjects are already familiar with the overall conceptual structure of the material. Armed with this familiarity, all knowledgeable subjects have to do in the reading phase is find out how the information in the text maps on to their prior conceptual understanding. However, the non-knowledgeable subjects have both to familiarise themselves with the concepts and to discover the structure of the text. Once they have done this, then as long as they can use the map, their navigation is as good as that of the knowledgeable subjects. Our findings concur with those of Monk et al. [11] and Simpson and McKnight [5] who also found that the provision of a spatially based map depicting the relationships between various parts of the text resulted in more efficient navigation behaviour. However, by using both knowledgeable and non-knowledgeable subjects we have also been able to show that a map enables non-knowledgeable subjects to navigate as well as knowledgeable subjects, once they have familiarised themselves with the material.

The analysis of the questionnaire data supported the above observations. Subjects who had used the map reported having experienced fewer navigational problems than subjects who had used the contents list, who in turn, reported fewer navigational problems than subjects in the basic hypertext condition. Knowledgeable subjects reported fewer feelings of disorientation than non-knowledgeable subjects.

The initial reading of non-knowledgeable subjects was less affected by navigational aid than was their navigation. The difference between non-knowledgeable subjects and knowledgeable subjects disappeared in the map condition on the navigation measures but not on the reading measures. Reading was facilitated for both non-knowledgeable subjects and knowledgeable subjects mostly by the map but also by the contents list, and knowledgeable subjects outperformed non-knowledgeable subjects in all three navigational aid conditions. In line with the discussion above, these results are what we would expect if non-knowledgeable subjects are struggling with both content and structure in the reading phase, while knowledgeable subjects are only having to map the content onto their existing conceptual structures. Consistent with previous findings (McDonald and Stevenson [6], in press), we also found that subjects in the hypertext condition opened fewer nodes during reading, often neglecting to view entire sections of the document altogether. Moreover, it was observed that these subjects opened the same few nodes repeatedly, a browsing behaviour which suggests they were experiencing disorientation.

The difference in overall performance between subjects in the pure hypertext condition and those in the map and contents list conditions is hardly surprising when it is considered that hypertext alone does not make it easy for the user to know what information is available or which parts of the text remain to be seen. The performance of hypertext users may suffer because they must simultaneously focus on the task in hand, such as retrieving information, and on orienting themselves in the hypertextual space. In other words, they must decide which routes will satisfy their information goals, execute these routes, keep track of digressions, and also monitor what information they have already viewed. Navigational aids reduce this load on the user’s working memory by helping them with the task of orientation.

Perhaps more interesting is the difference in performance of subjects in the map and contents list condition. The performance of both knowledgeable and non-knowledgeable
subjects in the map condition was superior to their performance in the contents list condition, on all the measures. The most likely reason for these differences in performance between the two aids is by the way in which they tackle the problem of disorientation. The textual contents list simply provides the user with an indication of what material is in the document, it does not offer guidance on the particular route the user should follow in order to arrive at their destination. The map however, allows users to gain an overview of the available information, and because it depicts the relationships between various nodes, and allows users to plan and execute routes through the document.

These findings have two important implications for hypertext. First of all, they suggest that the type of navigational aids employed should take into account the background knowledge of the user. Specifically, non-knowledgeable subjects seem to benefit most from a spatially organised map. Second, it seems that the provision of a spatial map may act as a catalyst for the development of spatial knowledge and possibly also conceptual knowledge. As such, navigational performance in hypertext seems to be markedly improved by the provision of navigational aids, especially with a localised map. However, as Gupta and Gramopadhye [9] have shown, navigational tools, and spatial maps in particular are not always effective because they may clash with other factors such as document size. Some hypertexts may contain hundreds if not thousands of nodes, with a myriad of links between them. Clearly, documents of this size would not easily lend themselves to diagrammatic representation. It is doubtful that maps of such large documents would be able to be displayed on screen in their entirety, and there is the very likely possibility that users would have great difficulty in understanding such complex data structures. However, our study has shown that localised maps can be effective, and so we would recommend that if a spatial representation is to be employed then localised or fish-eye maps should be used.

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