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Disorientation in hypertext: the effects of three text structures on navigation performance

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A study is described which examines the effects of two hypertext topologies (hierarchy and non-linear) on navigation performance compared to a linear version of the same document. Subjects used the document to answer 10 questions. After a distraction period, subjects returned to the document to locate five specified nodes. Speed and accuracy measures were taken, and the subjects' own evaluation of their performance was assessed using a questionnaire. The results showed that subjects performed better with the linear text than with the non-linear text, while performance on the hierarchical document fell between these two extremes. Analysis of the questionnaire data confirmed these differences. The results are discussed in terms of their implications for computer-assisted learning systems.

Keywords: disorientation, hypertext, navigation

Hypertext systems have the potential to change the way we think about and use educational texts. The main distinction between hypertext and more traditional forms of computer-based instruction is that hypertext allows rapid non-linear access to large amounts of information, and extends the user's control giving them the freedom to explore the document according to their information needs. However, there is little evidence to suggest that users can, in practice, manage the unusually high level of control that hypertext gives them. Indeed, many researchers have commented that hypertext users often get lost or become disorientated (Foss, 1989; Hammond, 1989; Hammond and Allinson, 1989; Smith and Wilson, 1993). The aim of this study is to examine empirically the problem of disorientation in hypertext, and to identify the information structures which appear to lead to its occurrence.

Shin *et al* (1994) suggest that the most popular structures for hypertext are hierarchical and network structures. As the name suggests, hierarchical structures allow the nodes to be connected to form a strict hierarchy, where a node at one level can only access nodes directly above or below. These structures are said to contain organisational links (Locatis *et al*, 1989). Network structures allow a node to be connected to any other node in the hypertext to form a complex structure with many links, often referred to as referential links (Locatis *et al*, 1989). However, the position is unclear as to which structure is more likely to be easy to use and to foster learning. Studies conducted by Van Dyke Parunak (1989) and Batra *et al* (1993) suggest that hypertext structure may affect an individual's ability to locate and extract information. Batra *et al* (1993) examined the effects of two hypertext topologies, hierarchical and hypertorus (nodes are arranged in a rectangular pattern), on subjects' ability to locate the answers to 10 questions using the hypertext. Their findings suggest that the hypertorus structure fostered more exploratory browsing, but subjects found it significantly easier to locate required information using the hierarchy. It is not surprising that the type of structure employed may effect an individual's ability to use the system efficiently. As the number of links increases so will the amount of choice offered to the user, in terms of the different routes they may follow. While this necessarily increases the degree of control the user may impose on the learning situation, it also increases the opportunities for disorientation. Consequently, the issue has some important implications for hypertext's future use, especially in terms of its educational value.

The merits of using hypertext materials in an instructional setting have been an issue of debate for some time now. Educators appear to be captivated by hypertext's promise of a more learner-centred style of computer based instruction. Hypertext's comparative

flexibility and the fact that it places much of the responsibility for learning squarely on the shoulders of the individual learner, means that it is an attractive proposition to those educators who view the model learner to be self-motivated, and perhaps capable of managing the complex and often discomforting process of learning as understanding (Stevenson and Palmer, 1994).

Although this somewhat revolutionary approach to the creation of educational materials offers some exciting possibilities in the realm of user centred learning, it brings with it some unfortunate consequences. Users may often be overwhelmed, confused or disorientated by the sheer amount of choice offered by the hypertext, to the extent that they lack a clear understanding of the relationships that lie within the system (Elm and Woods, 1985). In other words, they are unable to make informed decisions about which paths to follow in order to satisfy their information/learning goals. In some cases the disorientated reader can miss entire sections of the hypertext document altogether, demonstrating a lack of closure (Hammond, 1989; Shneiderman, 1987; Smith and Wilson, 1993).

Foss (1989), has identified several other potential difficulties hypertext users may experience. Foss grouped these problems under two headings; The Embedded Digression Problem and The Art Museum Phenomena. The Embedded Digression Problem embraces the difficulties which arise from the multiplicity of choice offered by most hypertexts. Users may delve into a richly connected network of information which may serve to distract them from their chosen path and cause them to lose their place in the document. Alternatively, users may forget to return from a digression or forget to follow an interesting path they had planned earlier. The Art Museum Phenomena refers to a group of problems associated with learning through browsing. Browsing is an open and exploratory information-seeking activity which involves scanning and tracing ideas from one node to another (McAleese, 1989) in an often vague and non-specific manner (Batley, 1989). The non-directive nature of browsing means that users may often wander through a hypertext without stopping to study or think about the ideas the document presents. Consequently, users may be unable to recognise which nodes have been visited, or which parts of the document remain to be seen.

These difficulties may severely hinder the learning process in two ways. Firstly, if learning is to occur, readers must be able to form a coherent understanding of the information they have read. This process may be impeded when there is interference from the sheer amount of information viewed, to the extent that users may not be able to remember what information has been examined. Secondly, as Tripp and Roby (1990) point out, learning may also suffer because the hypertext reader will have fewer mental resources directed toward the learning task, because they will have to focus on re-orienting themselves within the hypertextual space.

Collectively, the problems described above have come to be known as the disorientation or navigation problem (Conklin, 1987; Dillon *et al*, 1993; Edwards and Hardman, 1989). This unfortunate state of affairs may have a markedly adverse effect on the users' performance, meaning that they may be unable to locate and extract the information they require. It could be argued that this problem is not exclusive to hypertext; it is reasonable to suggest that readers of traditional linear texts may also experience disorientation. However, linear texts such as a book or journal article provide the reader with several orientation and discourse cues, such as page numbers, chapter headings and running titles, to help the reader re-gain his/her bearings. The hypertext reader, however, is not usually offered such luxuries. Contents listings, page numbers and indices for example, are not an integral part of every hypertext, and the underlying structures of these documents can be quite different from what the average reader might expect. When you consider the disorientation problem coupled with a general inexperience of learning by browsing, it is small wonder that many regard the use of hypertext in education as a recipe for disaster.

There appears to be a growing consensus among researchers in the area that disorientation is hypertext's major limiting factor (Batra *et al*, 1993; Edwards and Hardman, 1989; Gygi, 1991; Hammond, 1989; 1993; Monk *et al*, 1988; Nielsen, 1990; Oborne, 1990; Raskin, 1987; Smith and Wilson, 1993). For the purpose of experimental study, most researchers have adopted Elm and Woods' (1985) definition of disorientation as a degradation in user performance. Typically the disorientated user takes longer to find the information they require because they are unable to plan specific routes through the document, and are less accurate at extracting relevant information. Consequently, most experimental investigations of the problem are based around a question–answer task, in which the subject searches the hypertext for the answers to several questions. The measures taken generally include the time spent viewing an index (McKnight *et al*, 1990), the time taken to complete the task (Edwards and Hardman, 1989; Leventhal *et al*, 1993; McKnight *et al*, 1990; Mohageg, 1992; Rada and Murphy, 1992), the accuracy of the subject's chosen route (Leventhal *et al*, 1993; Mohageg, 1992; Rada and Murphy, 1992) and the accuracy of their responses (Edwards and Hardman, 1989; Leventhal *et al*, 1993; McKnight *et al*, 1990; Mohageg, 1992; Rada and Murphy, 1992). The results of these studies, with the exception of Mohageg (1992), demonstrate that hypertext users are generally slower at answering questions and are less accurate, when compared to subjects who viewed the same materials presented in either paper format or as a linear document presented via a computer. [Mohageg (1992) found that subjects using a hierarchically structured hypertext performed significantly faster on a question–answer task than subjects who had used a linear version of the same document. However, the questions used had been previously judged by expert programmers to be more suited to a hierarchically organised document.]

For example, McKnight *et al* (1990) examined subjects' performance on a question–answer task when using one of four versions of the same document (two hypertexts, one word processed file and a paper version). In addition to speed and accuracy data, McKnight *et al* investigated the time spent viewing the index and the contents list as a measure of navigational

difficulties. Their results show that subjects using the linear documents spent considerably less time viewing the index and contents list, and were more successful in locating the answers to the questions. These results together with those of other studies cited above, suggest that the subjects in the hypertext conditions experienced some navigational problems, and as such can be said to be disorientated.

The aim of the current study is to examine the problem of disorientation in hypertext empirically, and to identify the factors which appear to lead to its occurrence. This study examines the effects of two hypertext topologies (hierarchical and non-linear) on navigation performance as compared to a linear version of the same document. In line with previous studies, speed, accuracy and the subjects' movements through the document were recorded. In addition, questionnaire data were obtained to assess the subjects' own impressions of their interaction with the system. The experimental method used in the study is similar to those used in the studies described above. It is expected that the performance of subjects in the linear condition will be superior to that of subjects in the hierarchy and non-linear conditions. In turn, it is also expected the subjects using the hierarchically structured document should perform better than those using the non-linear document.

Method

Subjects

Twelve postgraduate students participated in the study, five males and seven females. Their ages ranged between 21 and 37 years. All subjects had some previous experience of using computers. Subjects were tested individually.

Materials

The hypertext document used in the experiment is called 'The Nature of Human Learning'. This text-based document of approximately 4500 words in length presents a discussion of the psychological processes underlying human learning. The text was taken from: 'Language, Thought and Representation' by R.J. Stevenson (1993) and 'Learning: Principles, Processes and Practices' by R.J. Stevenson and J.A. Palmer (1994). The text was adapted for use in hypertext format by the present authors. Each hypertext document contained the same information but had a different structure. The three structures examined in this study were linear, hierarchical and non-linear. The linear document had a sequential structure, where each node appeared in a fixed linear sequence. Movement through the document was achieved by the means of 'Next' and 'Previous' buttons, which caused the next or previous card in the stack to be displayed.

The cards in the hierarchical document were linked to form a strict hierarchy (one parent node for any number of child nodes). Subjects moved through the document by clicking on text buttons – highlighted words appearing within the body of the text. Clicking on a text button, caused a card bearing the same name as the button to be displayed. The document also included a backtrack facility.

The cards in the non-linear document were linked to form a network based on a number of cross-referential links, in which any card could be connected to any number of other cards. A link was established via keywords or text buttons in the text of each node, to other related nodes. As in the hierarchically structured document, subjects moved through the hypertext by clicking on text buttons. The document also included a backtrack facility. The principle distinction between the hierarchically structured and non-linear documents is that the hierarchy provides more of a framework to guide the users' exploration, whereas the non-linear structure is essentially formless, and exercises no control over the users' movements. Since the subjects were unaware of the structure of the document they read, the information they gained while reading and the ease of use was solely determined by the subjects' experiences while navigating the document.

The hypertext documents were implemented using HyperCard 2.2, a card based environment where a card of information corresponds to a hypertext node. Each card was composed of a separate title and text field containing no more than eight lines of New York 16 pt text. The test document consisted of 45 individual cards. The cards were displayed on a coloured background. The documents were displayed using a 14 inch Macintosh colour monitor. The subject's activities were monitored throughout the experiment.

Design

The experiment used a between subjects single factor design. The independent variable was hypertext topology – hierarchical, non-linear and linear. The dependent variables were mean time to answer questions, accuracy, mean number of additional nodes accessed per question, subjects' estimates of document size and the number of cards opened during browsing. Subjects were randomly assigned to one of the three experimental conditions.

Procedure

At the start of the experiment each subject was asked to complete a questionnaire on their computer experience. To ensure an equivalent level of interaction each subject was then asked to read a computerised tutorial which explained how to use the hypertext document. Each tutorial was tailored for the type of document the subjects would be using during the experiment (linear, hierarchical and non-linear). Any questions the subject had were answered before the experiment began. The experiment then progressed in the following five stages.

Stage one: reading task

In order to familiarise themselves with the hypertext document the subjects were required to read the hypertext until they thought they had read the whole document. They were then asked to make an estimate of the document's size in approximate number of cards. The number of cards opened during reading and each subject's size estimate were recorded.

Stage two: question answering task

Subjects were then required to use the hypertext document to answer 10 questions. For example, *What is*

a heuristic? The answers to the questions could be found in specific cards in the document. Subjects were instructed to navigate through the hypertext document to locate the answers. Once they had located the answer to a question, they clicked on the 'answer' button, and reported their response to the experimenter. They were then taken back to the start screen, and given the next question.

The presentation order for the 10 questions was randomised for each subject. Each question was printed on a card, and was handed to the subject by the experimenter. The subjects were instructed that they should still search for the relevant card even if they believed that they already knew the answer to a question. The subjects were instructed to answer the questions in the order in which they were given. The number of cards opened over and above the minimum needed to locate each answer, the time taken to find the answers and the accuracy of the subjects' responses were recorded.

Stage three: distraction task

The subject's attention was directed away from the hypertext by the use of a distraction task. Subjects were asked to complete the spatial sub-scale of the AH5 test (data not reported here). They were then taken back to the hypertext to complete the card location task.

Stage four: card location task

Subjects were instructed to navigate through the hypertext in order to locate five target cards. This measure was incorporated to assess whether the subjects had anough knowledge of the system to be able to re-orient themselves after a distraction. At the start screen, the subjects were handed a piece of card with the title of a specific node printed on it, they then searched for the appropriate card. Once they had found the target card they were taken back to the start screen and were given the next card to search for. The number of cards opened over and above the minimum needed to locate each target card, and the time taken to find the cards were recorded. Since this study is primarily concerned with disorientation in hypertext the only search strategy available to the users was exploratory browsing. No additional search facilities were incorporated into the hypertext document.

Stage five: questionnaire

Finally, in order to elicit information about the quality of the subject's interaction, subjects were asked to complete a questionnaire. The questionnaire was developed as a Likert scale, with two scales examining user disorientation and subjects' perceptions of their learning. The initial questionnaire was subjected to an item analysis which led to four of the original items being discarded. The final questionnaire consisted of 20 items, half positive and half negative in tone. A typical item on the disorientation scale was: '*When using the document I often had difficulty in deciding where to go next*'. A typical item on the perception of learning scale was: '*I feel I have gained an understanding of the information contained in the document*'.

Under each item a five point scale was presented, ranging from strongly agree, to strongly disagree. Subjects circled the response they wished to make.

Results

Reading: number of cards opened

The number of cards opened by each subject during the reading phase was determined. The top row of *Table 1* presents the mean number of cards opened per condition for the reading phase.

A one-way ANOVA revealed a significant effect of subject group. [$F(2,9) = 18.03$, $p < 0.07$]. Tukey HSD tests indicated significant differences between each condition: linear vs non-linear, [$Q(3,9) = 8$, $p < 0.01$]; linear vs hierarchy [$Q(3,9) = 4$, $p < 0.05$]; hierarchy vs non-linear [$Q(3.9) = 4$, $p < 0.05$].

Reading: estimate of document size

After the reading phase, subjects were asked to estimate the size of the document in approximate number of cards. Each document contained 45 cards. The bottom row of *Table 1* presents the mean estimate of the document's size for each condition.

A one-way ANOVA revealed a significant effect of subject group [$F(2,9) = 4.76$, $p < 0.04$]. Tukey HSD tests indicated significant differences between the linear vs non-linear condition only [$Q(3,9) = 4.32$, $p < 0.05$]. Subjects in the linear condition tended to predict the size of the document more accurately than subjects in the non-linear condition, who on average grossly underestimated the size of the hypertext document.

Question answering: accuracy

The number of questions each subject answered correctly was recorded. One point was awarded for a correct answer, zero points were awarded for an incorrect answer. Each subject achieved the maximum 10 points, across the three conditions.

Question answering: time taken

The total time taken to answer the 10 questions using the hypertext document was calculated for each subject. The mean time per condition is presented in the top row of *Table 2*.

A one-way ANOVA revealed a significant effect of subject group [$F(2,9) = 34.82$, $p < 0.01$]. Tukey HSD tests indicated significant differences between all three conditions: linear vs hierarchical [$Q(3,9) = 4.97$, $p < 0.01$]; linear vs non-linear [$Q(3,9) = 11.76$, p 0,01]; hierarchy vs non-linear [$Q(3,9) = 6.79$, $p < 0.01$]. Subjects in the linear condition answered the questions

Table 1 Mean number of cards opened, and estimates of documents size per condition during the reading phase

	Linear	Hierarchy	Non-linear
Mean number of cards opened	45.75	37.25	28.75
Mean estimate of document size	42.42	35.85	25.10

Table 2 Mean time per condition (in sec) and the mean number of additional cards opened per condition for the question answering task

	Linear	Hierarchy	Non-linear
Mean time	75.63	86.19	100.62
Mean number of additional cards	1.2	7.8	11.3

Table 3 Mean time per condition (in sec) and the mean number of additional cards opened per condition, for the card location task

	Linear	Hierarchy	Non-linear
Mean time	77.67	107.21	115.56
Mean number of additional cards	2.25	7.95	12.7

significantly faster than subjects in the hierarchical condition, who in turn responded faster than the subjects in the non-linear condition.

Question answering: number of additional cards opened

The number of additional cards opened by each subject to locate the answers to the 10 questions was calculated. Specifically, the least number of cards that it was necessary to open in order to locate each target answer was determined. This figure was then subtracted from the actual number of cards opened by each subject. The mean number of additional cards opened for each of the three conditions is presented in the bottom row of *Table 2*.

A one-way ANOVA revealed a significant effect of subject group [$F(2,9) = 34.88$, $p < 0.01$]. Tukey HSD tests indicated significant differences between all three conditions: linear vs hierarchical [$Q(3,9) = 7.58$, $p < 0.01$]; linear vs non-linear [$Q(3,9) = 11.63$, $p < 0.01$]; hierarchical vs non-linear [$Q(3,9) = 4.05$, $p < 0.05$]. Subjects in the linear condition opened fewer additional cards than those in the hierarchical condition, who in turn opened fewer cards than subjects in the non-linear condition.

Card location task: time taken

The total time taken to locate the five target cards using the hypertext document was calculated for each subject. The mean times per condition are presented in the top row of *Table 3*.

A one-way ANOVA revealed a significant effect of subject group [$F(2,9) = 35.40$, $p < 0.01$]. Tukey HSD tests indicted significant differences between the linear vs hierarchical condition [$Q(3,9) = 8.83$, $p < 0.01$]; and linear vs non-linear condition [$Q(3,9) = 11.32$, $p < 0.01$] only. Subjects in the linear condition located the five target cards significantly faster than the subjects in both the hierarchical and non-linear conditions.

Card location task: number of additional cards opened

The number of additional cards opened by each subject to locate the five target cards was calculated. Specifically, the least number of cards that it was necessary to open in order to locate each target was determined. This figure was then subtracted from the actual number of cards opened by each subject. The mean number of additional cards opened for each of the three conditions is presented in the bottom row of *Table 3*.

A one-way ANOVA revealed a significant effect of subject group [$F(2,9) = 33.09$, $p < 0.01$]. Tukey HSD tests indicated significant differences between all three conditions: linear vs hierarchical [$Q(3,9) = 6.27$, $p < 0.01$]; linear vs non-linear [$Q(3,9) = 10.45$, $p < 0.01$]; hierarchical vs non-linear condition [$Q(3,9) = 5.22$, $p < 0.05$]. Subjects in the linear condition opened fewer additional cards than those in the hierarchical condition, who in turn opened fewer cards than subjects in the non-linear condition.

Questionnaire data

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. One point was awarded for strongly agreeing with a negative statement, and five points for strongly disagreeing with a negative statement. The scale was reversed for positive items. The top row of *Table 4* presents the total scores per condition for the disorientation scale, and the bottom row for the perceptions of learning scale.

The questionnaire data were analysed using a Kruskall–Wallis test on the two scales of disorientation and perceptions of learning. For the disorientation scale the test revealed significant differences among the three groups [$H9,85$, $df = 2$, $p < 0.07$]. Analysis of the perceptions of learning scale also revealed a significant difference [$H7.84$, $df = 2$, $p < 0.0198$].

Further analysis of the disorientation scale using Mann–Whitney tests revealed significant differences between scores for all three groups: linear vs non-linear [$Z = -2.31$, $p < 0.04$]; linear vs hierarchical [$Z = -2.31$, $p < 0.04$]; hierarchy vs non-linear [$Z = -2.31$, $p < 0.04$]. Subjects using the linear document rated themselves as having experienced significantly fewer navigational problems than subjects using the hierarchical document who, in turn, rated themselves as having experienced fewer navigational problems than subjects using the non-linear hypertexts.

Further analysis of the perceptions of learning scale using Mann–Whitney tests revealed significant differences between scores for the linear and non-linear conditions [$Z = -2.32$, $p < 0.04$] and between the linear and hierarchical conditions [$Z = -2.31$, $p < 0.04$] only. Perceptions of learning in the linear condition were more positive than those in either the hierarchical or the non-linear conditions.

Discussion

On all measures, except accuracy in answering the questions, performance on the linear text was signific-

Table 4 Mean scores per condition for the disorientation and perceptions of learning scales

	Linear	Hierarchy	Non-linear
Disorientation scale	64.75	27.5	18
Learning scale	2.5	13.5	11.5

antly better than performance on the non-linear text, while performance on the hierarchical text fell between these two extremes.

Thus, subjects appear to have little difficulty with linear texts, but demonstrate navigational problems, and appear to be disorientated, when the same text is presented as hypertext. In addition, subjects' performance is consistently worse when a non-linear structure is used than when a hierarchical structure is used. Furthermore, the subjects' own evaluation of the task as measured by the questionnaire was consistent with their performance measures. Subjects using the linear text rated themselves as having learnt more from the interaction period, and as having experienced little or no disorientation, than subjects who had used the non-linear text, and again ratings of subjects using the hierarchical text fell between these two extremes.

The superior performance of subjects using the linear document held for all stages of the experimental task. The results for the reading stage demonstrate that subjects using the linear document examined more cards than subjects in the non-linear and hierarchical hypertext conditions, and that subjects in the hierarchical condition examined more cards than those in the non-linear condition.

Subjects using the non-linear document opened fewer cards during the reading stage, indicating that they had neglected to view entire sections of the document, and demonstrating what Shneiderman (1987) refers to as a lack of closure. Moreover, it was observed that during this period these subjects tended to open the same few cards repeatedly, a browsing behaviour that suggests they were disorientated. This pattern of interaction has previously been observed by Simpson and McKnight (1990).

Subjects in the linear condition also provided more accurate estimates of document size than those subjects using the non-linear hypertext, who grossly underestimated the size of the document. These findings support in part those of McKnight *et al* (1990). McKnight *et al*'s data show that subjects could estimate the size of a linear text more accurately than a hypertext version of the same document. In contrast to our findings, their data also showed that subjects using the hypertext tended to overestimate the document's size. However, the discrepancies in the findings of our study and those of McKnight *et al* may be accounted for by the different experimental task subjects were required to perform in the two studies. McKnight *et al*'s subjects were allowed 3 min in which to familiarise themselves with the document, they were then asked a series of questions pertaining to the document's size, whereas subjects in our study were allowed to view the document until they thought they had seen the whole document. It may be that because McKnight *et al*'s subjects only had a brief time in which to examine the document they may have realised that they had not seen the whole document which may have led them to over-estimate the document's size. In contrast, our subjects were instructed to continue reading the document until they felt they had read the whole piece. In general, these results add more weight to the argument that subjects using the non-linear hypertext demonstrate a lack of closure, in that they fail to recognise the extent of the network, and so appear to be disorientated.

Although there was no significant difference between the conditions for the number of questions correctly answered, there was a difference in the time it took subjects to find those answers, and in the number of cards opened over and above the minimum needed to find the answers. Subjects in the linear condition found the answers significantly faster than subjects in the hierarchy and non-linear conditions, and opened fewer additional cards. Similarly, subjects in the hierarchy condition performed significantly faster, and opened fewer cards than their non-linear counterparts. Moreover, subjects in the linear condition performed significantly faster, and opened fewer additional cards to locate the five target cards after the distraction task, than subjects using the hierarchical and non-linear hypertexts. There was no significant difference in the time it took subjects using the hierarchical and non-linear document to locate the five cards. However, subjects using the hierarchical document opened significantly fewer cards than their non-linear counterparts.

The superior performance exhibited by subjects using the linear document implies that those using the non-linear and to a lesser extent the hierarchical document experienced disorientation. Subjects using the linear document had a better idea of the spatial location of the text within the document. This was probably because they realised that the information they needed could only be further back or further forward in the document. These findings provide support for those of McKnight *et al* (1990), who also found that their subjects performed better using a linear document than hypertext.

Although subjects using both the hierarchical and non-linear hypertexts appear to have experienced disorientation, subjects using the hierarchical document seemed to fare better than those using the non-linear hypertext. These findings lend support to those of Batra *et al* (1993) who found that hierarchical structures foster more efficient navigation behaviour than hypertorus structures, where the nodes are arranged in a rectangular pattern.

The analysis of the questionnaire data revealed a similar trend in performance. Subjects who had used the linear document reported having experienced significantly fewer navigational problems than subjects who had used the hypertext document. Moreoever, those subjects who had used the linear document reported feeling that they had learnt more about the knowledge domain, and expressed greater confidence in their ability to use the document than subjects in the hierarchical and non-linear conditions. The non-significant result between the hierarchy and non-linear conditions seems to indicate that subjects appear to be better at estimating feelings of disorientation than learning.

The difference in performance between the hierarchical and non-linear conditions may be accounted for by the disparate amount of choice offered to the user in terms of the number of links they may follow, and in the number of directions in which they may travel. Although the hierarchical document does not constrain the user to a single path through the document, its organisational structure does confine the user's movements, and necessarily their freedom to browse. However, the non-linear structure places no

constraints on the user's movements, they have unlimited freedom to explore a richly connected network of ideas. From the performance of subjects using this document it appears that this freedom does have its associated costs. The user must simultaneously focus on the task in hand, finding the answers to the questions, or locating the target cards, and on orienting themselves within the hypertextual space. This places a higher cognitive burden on the user in terms of the availability of their working memory resources. Consequently, their performance declines and they can be said to be disorientated. This situation is probably exacerbated by the unfamiliarity of such a structure, and learning through browsing.

Our results appear to have certain implications for the design of computer-aided learning systems. On the face of it, they seem to suggest that a linear text is preferable to a hypertext document for presenting learning materials, and that if a hypertext is used a hierarchical structure is preferable to a non-linear one. This is because subjects seem to find the information they require more efficiently in a linear document than in a hypertext document. However, this implication is based on the assumption that efficient navigation and hence efficient learning is preferable to slower navigation and learning, an assumption that may not be correct. As Schmidt and Bjork (1972) point out, the goal of learning is, or should be, to promote long term retention and the transfer of what has been learned to new contexts. They also point out that variables that maximise performance during training can be detrimental for long term retention and transfer. To take the example of transfer, Mannes and Kintsch (1987) asked subjects to study a text which was preceded by an outline or advanced organiser that had either the same or a different organisation as the text. When asked to recall the text subjects who had viewed the same-organisation outline performed better than those who had viewed the different-organisation outline. However, when subjects were asked to complete a problem solving task which required a deeper understanding of the text, the subjects who had used the different-organisation outline performed best. Thus, while initial learning was easier in the same-organisation group, transfer of learning was superior in the different-organisation group. Mayes *et al* (1990a; 1990b) make a similar point when they suggest that the disorientation induced by hypertext may be a desirable and necessary part of the process of understanding. What are needed, therefore, are tests of long term retention and tests of transfer after presentation of texts with different structures. Such tests will enable us to determine whether the efficiency of learning observed with linear texts carries over to long term learning and transfer, or whether the disorientation experienced with hypertext is the critical variable for successful learning.

We should also note that all subjects appeared to find the text quite simple. They all, regardless of experimental condition, correctly answered the 10 questions and located the five target cards. This was probably because the subjects were postgraduate psychology students, and so were already familiar with the basic concepts being discussed. We might expect performance to be less accurate if beginning undergraduates are used. Such a study is currently underway. Finally, it should be borne in mind that only 12 subjects participated in the study. Consequently, some caution is needed when interpreting the results.

In general, however, our conclusions are that, disorientation is a problem for hypertext users and that hypertext topology affects navigation performance. Specifically, non-linear texts are a greater problem for users than hierarchical texts. It appears therefore, that although non-linear networks capture the real essence of hypertext, users are unable to manage the freedom they are given. Moreover, the users themselves appear to be uncomfortable with this presentation medium, and express a lack of confidence in their own ability to use hypertext. However, it is necessary to test long-term retrieval and transfer, as well as short term retention before the implications of results such as these for the design of learning systems can be established.

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References

Batley, S. 1989 'Visual information retrieval: browsing strategies in pictorial databases' Unpublished PhD thesis, University of Aberdeen

Batra, S., Bishu, R.R. and Donohue, B. 1993 'Effects of hypertext topology on navigational performance' *Advances in Human Factors and Ergonomics* **19** 175–180

Bernstein, M. 1991 'Position statement for panel on structure, navigation and hypertext: the status of the navigation problem' in *Hypertext '91. Proceedings of the Third ACM Conference on Hypertext* The Association for Computing Machinery, New York, pp 365–366

Brown, P. 1989 'Do we need maps to navigate around hypertext?' *Electronic Publishing – Origination, Dissemination, and Design* **2** 91–100

Campagnoni, F.R. and Erlich, K. 1989 'Information retrieval using a hypertext based help system' *ACM Transactions on Information Systems* **7** 271–291

Conklin, J. 1987 'Hypertext: an introduction and survey' *Computer* 17–41

Dillon, A., McKnight, C. and Richardson, J 1993 'Space – the final chapter or why physical representations are not semantic intentions' in **McKnight, C., Dillon, A. and Richardson, J. (eds)** *Hypertext: a Psychological Perspective* Ellis Horwood, London, pp 169–191

Edwards, D. and Hardman, L. 1989 ' "Lost in Hyperspace" cognitive mapping and navigation in a hypertext environment' in **McAleese, R. (ed)** *Hypertext: Theory into Practice* Intellect, Oxford, pp 90–105

Elm, W. and Woods, D. 'Getting lost: a case study in interface design' in *Proceedings of the Human Factors Society 29th Annual Meeting*, pp 927–931

Foss, C. 1989 'Tools for reading and browsing hypertext' *Information Processing Management* **25** 407–418

Gygi, K. 1991 'Recognising the symptoms of hypertext' in **Laurel, B.** *The Art of Human–Computer Interface Design* Addison-Wesley, pp 279–287

Hammond, N.V. 1989 'Hypermedia and learning: who guides whom?' **Maurer, H. (ed)** *Computer Assisted Learning* Springer, Berlin

Hammond, N.V. and Allinson, L. 1989 'Extending hypertext for learning: an investigation of access and guidance tools' in **Sutcliffe, A. and Macaulay, L. (eds)** *People and Computers V* Cambridge University Press, Cambridge

Hammond, N.V. 1993 'Learning with hypertext: problems, principles and prospects' in **McKnight, C., Dillon, A. and Richardson, J. (eds)** *Hypertext: a Psychological Perspective* Ellis Horwood, London, pp 51–70

Landow, G. 1990 'Popular fallacies about hypertext' in **Jonassen, D.**

and Mandl, H. (eds) *Designing Hypermedia for Learning* Springer, Berlin, pp 39–60

Landow, G. 1991 'Position statement for panel on structure, navigation and hypertext: the status of the navigation problem' in *Hypertext '91 Proceedings of the Third ACM Conference on Hypertext* The Association for Computing Machinery, New York

Leventhal, L.M., Teasley, B.M., Instone, K., Rohlman, D.S. and Farbat, J. 1993 *Behaviour and Information Technology* **12**(3), 149–164

Locatis, C., Letourneau, G. and Banvard, R. 1989 'Hypermedia and instruction' *Educational Technology Research and Development* **37**, 65–77

Mannes, S.M. and Kintsch, W. 1987 'Knowledge organisation and text organisation' *Cognition and Instruction* **4**, 91–115

Mayes, J.T., Kibby, M.R. and Anderson, T. 1990a 'Learning about learning from hypertext' in **Jonassen, D.H. and Mandl, H. (eds)** *Designing Hypermedia for Learning* Springer

Mayes, J.T., Kibby, M.R. and Anderson, T. 1990b 'Signposts for conceptual orientation: some requirements for learning from hypertext' in **McAleese, R. and Green, C. (eds)** *Hypertext: State of the Art*

McAleese, R. 1989 'Navigation and browsing in hypertext' in **McAleese, R. (ed)** *Hypertext: Theory into Practice* Intellect, Oxford, pp 5–38

McKnight, C., Dillon, A. and Richardson, J. 1990 'A comparison of linear and hypertext formats in information retrieval,' in **McAleese, R, and Green, C. (eds)** *Hypertext: State of the Art* Intellect, Oxford, pp 11–19

Mohageg, M.F. 1992 'The influence of hypertext linking structures on the efficiency of information retrieval' *Human Factors* **34**, 351–367

Monk, A.F., Walsh, P. and Dix, A.J. (eds) 1988 *A Comparison of Hypertext, Scrolling and Folding as Mechanisms for Program Browsing* Cambridge University Press, Cambridge

Nelson, T.H. 1981 *Literary Machines* Texas, San Antonio

Nielsen, J. 1990 'Through hypertext' *Communications of the ACM* **33**, 297–306

Osborne, D.J. 1990 'Browsing and navigation through hypertext documents: a review of the human–computer interface issues *Interface Multimedia* **1**, 22–32

Parunak, H.V.D. 1989 'Hypermedia topologies and user navigation' in *Hypertext '89 Proceedings* 43–50

Rada, R. and Murphy, C. 1992 'Searching versus browsing in hypertext' *Hypermedia* **4** 1–31

Raskin, J. 1987 'The hype in hypertext: a critique' in *Proceedings of the ACM Hypertext '87 Conference*, pp 325–330

Schmidt, R.A. and Bjork, R.A. 1992 'New conceptualisations of practice: common principles in three paradigms suggest new concepts for training' *Psychological Science* **3** 207–217

Shin, C.E., Schallert, D.L. and Savenye, W.C. 1994 'Effects of learner control, advisement, and prior knowledge on young students' learning in a hypertext environment' *Educational Technology Research and Development* **42** 33–46

Shneiderman, B. 1987 *Designing the User Interface: Strategies for Effective Human–Computer Interaction* Addison Wesley, San Francisco

Smith, P.A. and Wilson, J.R. 1993 'Navigation in hypertext through virtual environments' *Applied Ergonomics* **24**, 271–278

Stevenson, R.J. 1993 *Language, Thought, and Representation* Chichester, J. Wiley

Stevenson, R.J. and Palmer, J.A. 1994 *Learning: Principles, Processes and Practices* Cassell

Tripp, S.D. and Roby, W. 1990 'Orientation and disorientation in a hypertext lexicon' *J Computer-Based Instruction* **17**, 120–124