Hypertext, navigation, and learning: a psychological perspective

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Hypertext, Navigation, and Learning: A Psychological Perspective.

By

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DECLARATION

The research contained in this thesis was carried out by the author between October 1993 and April 1997 while a postgraduate student in the Department of Psychology at the University of Durham. None of the work contained in this thesis has been submitted in candidature for any other degree.

STATEMENT OF COPYRIGHT

Work for this thesis has resulted in the following publications:

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ABSTRACT

Hypertext has the potential to revolutionise the way we organise and read texts. Indeed, hypertext's non-linearity and enhanced learner control are regarded by many as being an enormous advantage over the traditional printed medium. However, there is evidence to suggest that users are unable to explore hypertext without experiencing navigational problems (Kim and Hirtle 1995).

The research presented in this thesis examined some of the problems associated with navigation and learning in hypertext. As regards navigation, it was found that disorientation is a problem for hypertext users and that text structure affects navigation performance. Non-linear texts are a greater problem for users than hierarchical and mixed texts (hierarchical with a small number of cross referential links). It appears therefore, that although non-linear networks capture the real essence of hypertext, users are unable to manage the freedom they are given. Disorientation also seems to be particularly marked for users who are unfamiliar with the subject matter of the text. However, the results show that the provision of localised spatial maps can minimise disorientation.

As regards learning, the results showed that although non-linear texts create navigational problems and disrupt learning at acquisition, they can lead to good long term retention. Indeed, the results suggest a dissociation between navigation and learning. That is, efficient navigation is not always a prerequisite of meaningful learning. Unfortunately, the results showed that subjects prefer linear text and believe that hypertext requires greater mental effort to understand largely because of the navigational problems it creates. One solution to this problem may be to provide some form of guidance such as a map. However, the structural information depicted in spatial maps does not appear to support learning. By contrast, a conceptual map can reduce (but not eradicate) disorientation and enhance learning at both acquisition and retention.

DEDICATION

This thesis is dedicated to the memory of my father who died before it was completed.

Adam McDonald

1926 - 1996

I will remember you always with love.

He was my North, my South, my East and West,
My working week and my Sunday rest,
My noon, my midnight, my talk, my song;
I thought that love would last forever: I was wrong.

The stars are not wanted now; put out every one;
Pack up the moon and dismantle the sun;
Pour away the ocean and sweep up the wood;
For nothing now can ever come to any good.

Extracts from Funeral Blues
W.H. Auden April 1936

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CONTENTS

FIGURES

Chapter 2

Chapter 4

Chapter 5

Chapter 6

TABLES

Chapter 4

1

Hypertext and navigation

Overview

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 users' 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; Smith and Wilson, 1993). The aim of this chapter is to review some of the navigational problems typically associated with hypertext.

What is Hypertext ?

The fundamental feature of hypertext is that readers are permitted to explore a network of ideas making on line decisions about what information to read and in what order. The basic components of any hypertexts are nodes and links. A node is a unit of information expressing a single concept or idea. Hypertexts may contain any number of nodes that are connected by hypertext links. Links provide the mechanism by which we may travel through hypertext jumping from node to node. Hypertext links are usually associated with specific parts of the nodes they connect rather than to the node as a whole.

Information access in hypertext

There are a number of ways in which users can gain access to information in hypertext. For example, through text string searches, and the use of interactive indexes. However, by far the most common method of information access in hypertext is through browsing.

Browsing is a general exploratory information seeking activity, in which the user's goals are not fully specified. In other words, the user wants to know what information is available and if it will be of interest. Browsing is distinct from navigation, which is a more directed activity, in which users know what information they require, and want to find it. Thus, although both browsing and navigation are more or less goal directed activities, with browsing, the user does not have a specific limited search query in mind.

The ability of users to explore an information base freely via browsing is one of the most important aspects of hypertext, and is often cited as the characteristic that sets hypertext apart from other database systems. (Carmel, 1992; Knuth and Brush 1989). Users browse in hypertext by visiting a set of related nodes through the traversal of hypertext links (Kim and Hirtle 1995; McAleese, 1989; Smith and Wilson, 1993). There will of course be individual differences in browsing. Canter, Rivers and Storrs, (1985) identified five different browsing strategies commonly used. Scanning (covering a large amount of material without depth), browsing (following a path until a goal is achieved), searching (explicit goal search), exploring (finding the extent of the information) and wandering (unstructured globetrotting). McAleese (1990) argues that all of the above strategies with the exception of wandering have a place within hypertext. However in the discussion that follows we will see that it is this strategy that is often most likely to be adopted by hypertext users, albeit unintentionally.

Browsing has been ascribed a number of desirable characteristics. For example, it has been said to foster discovery learning by allowing the user to explore hypertext freely without constraint, focusing on the nodes the learner finds interesting. Foss (1989) suggested that the browsing process allows users to learn about related concepts and re-define their information goals. Learning develops through exploration. McAleese (1990) suggests that browsing can enhance the learning of concepts. He also suggests that browsing can facilitate learning at a meta level. That is, learning what is known, how many concepts have been mastered, what they are, and also what is not yet known.

However, not all researchers share this enthusiasm. Raskin (1987) likens browsing to groping around. Moreover, the process of browsing is often a complex and demanding information processing activity, in which the user must perform several tasks at once. These include reading and understanding the text, identifying and following routes through the document, while keeping track of distractions or interesting diversions encountered on route (Kim and Hirtle, 1995). This places a high cognitive load on users and as a consequence they often experience disorientation (Conklin, 1987). The cognitive load of browsing may be further increased by the complexity of some hypertexts. Indeed, hypertext's flexibility means that a variety of information structures can be created ranging from simple structures with only a few links, to large information networks consisting of hundreds if not thousands of links. The next section examines some of the most popular structures for hypertext and how they may influence browsing and navigation.

Hypertext topologies

Hypertext nodes can be linked together to form a variety of structures offering different levels of user control in terms of the number of links users may choose to follow, and in the number of directions in which they may travel. Studies conducted by Parunak (1989) and Batra, Bishu and Donohue (1993) suggest that hypertext structure may affect the user's ability to locate and extract information. For example, 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 ten 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 affect 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 user control, it also increases the opportunities for disorientation.

Shin, Shallert and Saveney (1994) suggest that the two 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, Letourneau and Banvard, 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 foster ease of use, and facilitate navigation and learning. The supposed advantages of network structures are two fold. First, this type of structure is intended to make information more accessible to the reader. For example, in a hierarchically structured hypertext moving from the top of the hierarchy to a node at the bottom may require the user to traverse several links, whereas the identical trip in a network structure may only require a single link. Second, this type of structure allows the user greater non-linear access to the information. In other words, the reader may choose to follow a variety of paths through the document, increasing their control over the text. However, the advantages offered by non-linear texts may be severely limited, if users are unable to find their way around such unfamiliar and often complex information structures without experiencing navigational problems.

Indeed, some researchers feel that such texts are of limited value, especially to beginners in the subject matter of the text. For example, Brown (1989) argues that complex network hypertext is inappropriate for novice users and suggests that a simple hierarchical structure should be employed with only a few referential links that cut across the hierarchy. Mohageg (1992) examined the performance of subjects who were unfamiliar with the text topic on an information retrieval task with one of three differently structured hypertexts: hierarchical, network and a combination of the two. He found that the performance was poorest with the network structure, but that performance with the mixed structure was not better than with the hierarchical structure. Mohageg concluded, therefore, that a mixed structure did not lead to performance gains for beginners. However, Mohageg's mixed structure contained twice the number of links as either the hierarchical or network structure alone. Thus his mixed text was more complicated than the one recommended by Brown. Furthermore, his network structure had the same number of links as the hierarchical structure. This severely limits the number of nodes that can be directly accessed from a given node and is not in the real spirit of hypertext, which favours the establishment of many different links.

Disorientation

The problem of disorientation in hypertext is multi-faceted, and extends far beyond any subjective feelings of bewilderment or confusion the user might have. Indeed, it generally results in a measurable decline in user performance (Elm and Woods, 1985). Typically, the disorientated user is unable to gain an overview of the material, and encounters problems in deciding if the information they require is available, where to look for it, and how to get there (Edwards and Hardman, 1989; Gray, 1990; Hammond, 1989; McKnight, Dillon and Richardson, 1991; Wright and Lickorish, 1989).

In addition, Foss (1989) has identified several other potential difficulties hypertext users may experience in relation to disorientation. 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 indeed, forget to follow an interesting path they had planned earlier. The Art Museum Phenomena refers to a group of problems associated with browsing. Unfamiliarity with the subject matter or interference as a result of the sheer amount of information viewed may hamper the user's ability to integrate and understand the information being read. As a consequence users may often wander through hypertext without stopping to study or think about the ideas the document presents, and may be unable to recognise which nodes have been visited, or which parts of the document remain to be seen.

The empirical evidence regarding the problem of disorientation has shown that it has the potential to disrupt both browsing and navigation in hypertext. Typically, the disorientated user generally takes longer to locate information on an information retrieval task (Edwards and Hardman, 1989; Leventhal et al, 1993; McKnight, Dillon and Richardson, 1990; Mohageg, 1992), are unable to follow direct rotes to the information they require (Leventhal et al, 1993; Simpson and McKnight, 1990; Rada and Murphy, 1992), and are less accurate when using the text to answer questions or retrieve facts (Edwards and Hardman, 1989, Mohageg, 1992). Studies have also shown that when hypertext users are left to decide what information to read, they often stop reading to soon, neglecting to view entire sections of the document, and have been observed to open the same few cards repeatedly rather than moving on to new previously unseen nodes (Simpson and McKnight, 1990). Moreover, Hammond (1989) suggests that the problem may also be particularly acute for those users who are unfamiliar with the subject matter of the text. Users who possess prior knowledge of the text topic will be able to draw upon this knowledge to help them control their navigation. Low knowledge users however, will have to depend upon structural cues presented in the text.

The cause of the problem seems to be due to the interaction of two factors. First, hypertext users must carry out several tasks at once. Kim and Hirtle (1995) have classified these tasks into three categories: navigational tasks, informational tasks and management tasks. Navigational tasks embrace the planning and execution of routes through the hypertext. Informational tasks involve reading and understanding the text content. Management tasks involve the co-ordination of navigational and informational tasks, including keeping track of interesting digressions encountered on route, and ensuring that a particular route satisfies the information need. The concurrent execution of these tasks places heavy demands on the user's working memory resources which can cause a decline in performance resulting in disorientation.

The second factor is what Woods (1984) refers to as the keyhole phenomenon. That is, only one hypertext node can be viewed at any one time, leaving the rest of the document hidden. Therefore the user may have problems understanding their position in the document relative to the network as a whole. As Wickens (1990) points out, successful navigation depends upon the existence of correspondences among the physical representation of the world (and the traveller's position therein), the travellers egocentric view of the world, (what is seen in the forward field of view) and the travellers mental representation of the world. When these correspondences are broken (e.g. by the keyhole phenomena) disorientation results.

It seems therefore, that hypertext's greatest strength - its potential for non-linear reading and extended user control - is also its greatest weakness in that it may distract, confuse or disorientate the user. Experiments 1, 2 and 3 of this thesis examine some of the navigational problems often experienced in hypertext by investigating the effects of a non-linear, and simpler hierarchical structure on users' ability to browse and navigate through hypertext compared to a linear version of the same document. Experiment 4 also examines the problem of disorientation in hypertext, and how text structures such as those suggested by Brown (1989) might facilitate navigation for subjects with different levels of prior knowledge of the text topic.

Spatial processing and hypertext navigation

This section examines human spatial processing and way finding research, that may provide some insight as to how we might successfully deal with the problem of disorientation in hypertext. The fact that users seem to have difficulty in finding their way through hypertext may be related to the type of spatial knowledge they have acquired of the system. According to Siegal and White (1975) and Thorndyke (1980), the development of spatial knowledge of a new environment progresses through three levels of representation. Initially we recognise landmarks, salient features of the environment such as a distinctive building or statue, that we use to guide our subsequent navigation. Landmark knowledge is followed by the development of route knowledge, which is characterised by the ability to navigate from one point in the environment to another, using existing knowledge of landmarks to guide decisions concerning when to take right or left turns. Although this representation is more advanced than landmark knowledge, an individual possessing route knowledge may still know very little about their surroundings. As Dillon (1994) points out, an individual may be able to get from A to B in a particular environment but they may not be following the most efficient route to their destination. Moreover, if we become lost as a result of a wrong turn, the information provided by route knowledge is rendered useless because we only have knowledge of one specific route rather than a global frame of reference (Wickens, 1984; Dillon, 1994). The final and most advanced level of representation is survey knowledge. Survey knowledge allows us to give directions to others, traverse unfamiliar routes, and know the general direction of places. As such, survey knowledge is based upon a global frame of reference in contrast to route knowledge which is based upon a more ego-centred perspective. The advantage of this level of representation becomes apparent when compared to the limitations of route knowledge. Unlike route knowledge, if we get lost, survey knowledge may be used to guide us back to either our original route or to our desired destination by means of a different route. This level of representation is often referred to as a cognitive map. Cognitive maps are internal mental representations of physical space, which we use to make sense of our environment (Kaplan, 1973; Kitchin, 1994; Tversky, 1992).

The study of spatial knowledge and the development of cognitive maps have largely been confined to the physical environment. However, Canter, Rivers and Storrs (1985) drew an interesting parallel between navigation in the physical environment, such as buildings or cities and navigation in complex data structures. Taking this parallel one step further, Edwards and Hardman (1989) and Simpson and McKnight (1990) have applied the insights gained about spatial knowledge of the physical environment to hypertext systems and have demonstrated that the probability of getting lost within hypertext may depend upon the user's ability to generate a cognitive map of the underlying structure of the hypertext nodes and links.

For example, Edwards and Hardman (1989) examined the effects of giving subjects navigational experience of a document, compared to a more direct access mechanism, on their structural knowledge of a hypertext document. Specifically, subjects were required to search through a specially designed hypertext in order to retrieve the answers to a number of questions. Subjects were also required to represent the document's structure as a cognitive map by arranging printed miniatures of each hypertext node on a white board as they imagined them to be arranged in the hypertext document. One group of subjects was allowed to navigate through the document following the hypertext node and links. A second group explored the document with the use of an interactive alphabetical index of all the hypertext nodes contained in the document. They were denied access to the hypertext links. Finally a third group of subjects were assigned to a mixed document in which subjects had access to the index but could also follow the hypertext nodes and links.

Edwards and Hardman found that the navigation condition provided more accurate representations of the document structure than subjects who had used the alphabetical index and mixed condition. They also found that knowledge of hypertext structure, (number of correctly placed nodes) was correlated with subjects' reports of feeling lost. That is, those subjects with low structural knowledge reported feeling lost more often than subjects with high structural knowledge. The poorer performance on the cognitive map task of subjects in the index condition is likely to be due to the fact that these subjects were denied access to the hypertext links. Consequently, they had no opportunity to familiarise themselves with the document's structure. Moreover, the index itself gave the user no cues as to the document's likely structure. Subjects in the mixed condition also fared badly on the cognitive map task. These subjects had access to both the index and the hypertext links, however, it seems likely that in this case, the index may have disrupted cognitive map development because subjects were able to access nodes that were completely unrelated to the nodes they had just been reading, without gaining knowledge of the routes that connect them. The poorer performance of subjects in the index and mixed conditions implies that the best way for subjects to get to know their environment is by direct navigation experience. Furthermore, Edwards and Hardman's results suggest that during navigation subjects attempt to construct a survey type representation of hypertext, and that efficient navigation is dependent upon the accuracy of this representation.

Studies of spatial cognition also tell us that the method by which people acquire spatial knowledge, will influence the type of knowledge they have and the way in which it is represented (Thorndyke and Stasz, 1980; Thorndyke and Hayes-Roth, 1982). Thorndyke and Hayes-Roth (1982) propose that individuals acquire different types of spatial knowledge from different sources. They suggest that people acquire survey knowledge from a map and that this knowledge resides in memory in images that can be scanned and measured like a physical map, enabling learners to produce accurate Euclidean (straight-line) distance estimates, and judge the location of objects relative to a fixed point. From direct navigation experience, people acquire procedural (route) knowledge of the routes connecting locations, including detailed information, such as impressions of the distance travelled along a particular route. Thorndyke and Hayes-Roth (1982) demonstrated that over time, extensive navigation in an environment will ultimately lead to the development of a more superior cognitive map of that environment. However, Thorndyke and Hayes-Roth have identified two factors that may interfere with the development of survey knowledge obtained through navigation. First, the regularity of the environment under study will affect the speed at which survey knowledge can be derived from navigation alone. Consequently, in complex irregular environments such as hypertext, we might expect the development of survey knowledge through direct navigational experience to be decelerated. Second, while the knowledge acquired from navigation may ultimately lead to the development of a superior mental representation, it is difficult to acquire and takes some considerable time to develop.

Probably the most common means by which people get to know their environment is through direct navigational experience. However, the distinction drawn above between the types of knowledge we may acquire from different sources of information has led Wickens (1985), Moeser (1988) and Hirtle and Hudson (1991) to suggest that a short cut to survey knowledge might be achieved through map study. For example, Moeser (1988) found that the performance of naive subjects who studied floor plans of a large hospital building on orientation tasks (including direction pointing and distance estimation) was more superior to that of nurses who had up to two years experience of working in the building. Thorndyke and Hayes-Roth (1982) found that subjects who memorised a map of the Rand Corporation building were better at distance estimation than subjects with a month's experience of working in the building on distance estimation.

The above findings have a number of important implications for navigation in hypertext. First, it is often the case, that in the situations where hypertext is employed, for example, information retrieval, users need to acquire survey knowledge about their environments very quickly. In other words it is not practical or even possible for them to gain survey knowledge of the environment by extensive navigation experience, although there is evidence to suggest that navigation in hypertext does improve as a result of practice (Rouet, 1992). Second, hypertext is by nature a very irregular environment, consequently, navigation alone may not be the most efficient way to obtain a well developed cognitive map. Therefore, it may be the case that the development of survey knowledge in hypertext users might be enhanced if they are given the opportunity to study a map of the database. Experiment 5 (Chapter 5) tests these ideas by comparing the performance of subjects who are allowed direct navigational experience in hypertext, with a group of subjects who are given a map of the system's structure to learn. The study also examines the relationship between spatial knowledge and level of domain knowledge. As we have already said, users who are knowledgeable about the subject matter of the text may be able to navigate more efficiently through hypertext than those users who are unfamiliar with the knowledge domain. It may be the case that domain knowledge may facilitate the development of a survey type representation of the physical layout of the text. Therefore it is necessary to examine how domain knowledge interacts with the means by which subjects get to know locations in hypertext.

Research has also demonstrated the importance of individual differences in spatial ability for efficient navigation in computerised systems. For example, Gomez, Egan, Wheeler, Sharma, and Gruchacz (1983) found significant correlations between spatial skills (spatial memory, and visualisation ability) and efficiency in locating items to be changed on a screen based editor. Similarly, Campagnoni and Ehrlich (1989) demonstrated that subjects with better visualisation skills were faster at retrieving information in hierarchically structured hypertext. The relationship between individual differences in spatial skills and navigation in hypertext is also examined in experiments 1, 2, 3, and 4 of this thesis.

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 (Allinson and Hammond, 1989). For example, Allinson and Hammond (1989) report the findings of an exploratory study which examined the use and effectiveness of navigational tools in hypertext. The tools or aids 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 while studying partially familiar material, whereas the index was used more often during information search. However, Edwards and Hardman (1989) and Gupta and Gramopadhye (1995) 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 and hamper cognitive map development due to the mismatch between the actual hypertext topology and the structural information provided by the tools. For example, an index might 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 indices and spatially based aids such as maps.

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 (1995) and Wright and Lickorish (1989) have demonstrated the usefulness of providing hypertext users with indices and contents lists. For example, Dee-Lucas and Larkin (1995) found that the provision of a contents list improves both navigation and memory for text topics. Similarly, Wright and Lickorish (1989) compared two differently structured hypertexts and two different navigation systems. One system involved the user jumping to and from a separate index card (index condition). The other system permitted jumping directly from the text page (page condition). One of the hypertexts was organised in five chapters which were listed at the bottom of the screen for the page condition and in a separate index for the index condition. The other document was structured as a hierarchy with three levels. Subjects answered a series of questions about the text to which they were assigned. The results showed that readers preferred index navigation for the first hypertext document, but for the hierarchical structured document they preferred page navigation and produced better performance. As the task made increasing demands on working memory the separation of the navigational aid from the text display began to affect performance. Wright and Lickorish concluded that different navigational systems are suitable for different circumstances.

Spatial maps

The spatial map or graphical browser presents an over view 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 is supposed to tackle the problem of disorientation by allowing users to gain an understanding of the relationships that lie within the system, and by helping then 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 (Conklin, 1987; Gupta and Gramopadhye, 1995). A hypertext system 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, 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 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, Walsh and Dix (1988) and Simpson and McKnight (1990) have found that maps can lead to more efficient navigation behaviour. For example, Monk et al (1988) 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 (1990) 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. Moreover, Hammond and Allinson (1989); Dee-Lucas and Larkin (1995); and Wenger and Payne (1994) 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 seems to suggest that a graphical representation map help users overcome some of the problems typically associated with disorientation. By contrast, Stanton, Taylor and Tweedie (1992) 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, lower perceived control over the system, and poor development of a cognitive map. In addition, Wenger and Payne (1994) found that a map had no effect on recall of hypertext structure.

However, what these studies and those concerning the use of other navigational aids fail to show, is how these navigational tools interact with the prior knowledge of the user. Hammond (1989) suggests that disorientation may be heightened for subjects who are unfamiliar with the knowledge domain of the text. Indeed, Shin, Shallert and Savenye (1994) 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 Experiment 6 (chapter 5) is to do just that, by comparing the effects of localised spatial maps and a textual contents list on the navigation performance of subjects with and without prior knowledge of the text topic.

Summary

The basic conclusion to be drawn from this chapter is that hypertext's greatest strength - its potential for user controlled non-linear access to information, is also its greatest weakness, in that the multiplicity of choice in most hypertext systems serves to confuse, distract, and disorientate the user.

However, a number of factors can affect a user's ability to navigate effectively in hypertext. These factors include text structure, prior knowledge, and the provision of navigational aids. The aims of the first six experiments presented in this thesis were to examine these factors in more detail. Experiments 1, 2 and 3, examine the effects of text structure on navigation performance. Experiment 4, looks at how modifications in text structure interact with the prior knowledge of the users to enhance or impede navigation in hypertext. Experiments 5 and 6, examine both the role of maps as navigational aids, and how such aids interact with users' background knowledge.

2

Learning from text

Overview

Learning through reading is an activity most of us engage in every day of our lives. Indeed, a vast research effort spanning several decades has focused on the identification of factors that facilitate the comprehension process. However, recent research suggests that one way to facilitate learning from text is to introduce difficulties for the learner, so that they have to engage more actively with the text, drawing upon their prior knowledge in order to interpret the text's meaning. In this chapter, I will examine the processes involved in text comprehension and the ways in which learning from text might be facilitated, but first, I will briefly outline some features of human learning by drawing an important distinction between memory and understanding.

Learning, understanding and memory

Hayes and Broadbent (1988) and more recently Stevenson and Palmer (1994) distinguish between two types of learning, implicit learning and explicit learning. Implicit learning occurs without conscious effort. Knowledge acquired through implicit learning is also implicit and can not be described directly, but can be determined from behaviours and actions. An example of implicit knowledge is our ability to use language.

By contrast, explicit learning occurs as a result of a deliberate effort to learn. Knowledge gained through explicit learning is easily described, although it can be very difficult to acquire. An example of explicit knowledge is knowing that H_2SO_4 is the chemical formula for Sulphuric acid. Stevenson and Palmer (1994) have identified three different kinds of explicit learning. Understanding, problem solving and memorisation.

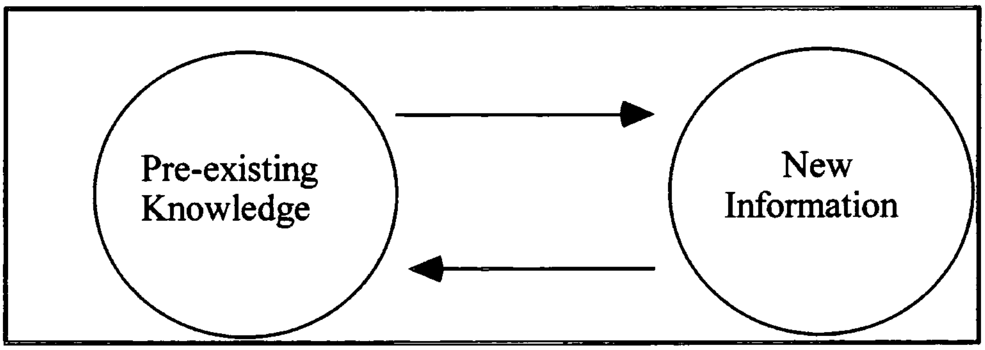
Learning as understanding involves the integration of new material with pre-existing knowledge. The new information itself is then used to update and modify pre-existing knowledge. Learning through problem solving results when the solution is found to a novel problem. With practice the solution will be retrieved automatically from memory, whenever the problem is subsequently encountered. Learning as memorisation involves the accumulation of information in long term memory. Material that has been integrated with pre-existing knowledge through deep semantic process is remembered better than material that has been committed to memory via simple repetition or rehearsal. Of the three kinds of learning identified by Stevenson and Palmer (1994) understanding and memorisation are of most importance and relevance to the research presented in this thesis. The following sections discuss memorisation and understanding in more detail.

Learning as understanding

According to Scardamalia and Bereiter (1991) learning is contingent upon a two-way interchange between the learner's pre-existing knowledge and the new information they wish to learn (see Figure 2.1). What Scardamalia and Bereiter call 'learning' is what Stevenson and Palmer mean by understanding.

Figure 2.1

The two-way process of understanding (adapted from Scardamalia and Bereiter 1991)



Specifically, for understanding to occur, the learner must use their pre-existing, or world knowledge to interpret the new material. They must then use this new information to update and evaluate their pre-existing knowledge. The use of pre-existing knowledge to interpret new material, and the subsequent use of new information to update and modify pre-existing knowledge structures is the cornerstone of conceptual understanding. The second part of this process is particularly important when the learner's pre-existing beliefs and ideas conflict with the new information to be learned. The facilitatory effects of pre-existing knowledge on learning have been widely demonstrated (see for example, Fincher-Kiefer, Post, Greene, and Voss, 1988; Kintsch, 1994; Moravcsik and Kintsch, 1993). However, as Stevenson and Palmer (1994) point out, when pre-existing knowledge conflicts with new information it can have quite a detrimental effect on learning, mainly because in such cases pre-existing knowledge can be extremely resistant to change. Consequently, if learners fail to engage in this evaluative process, the dissonance between the new information and their pre-existing knowledge will remain unchecked and they will hold conflicting beliefs.

Unfortunately, using new information to update pre-existing knowledge is a highly demanding process. Not only because it places severe demands on working memory, but also because it requires the learner to employ high level metacognitive skills (Stevenson and Palmer, 1994). That is, the learner must reflect upon the adequacy and state of their own knowledge, recognise inconsistencies or knowledge gaps and actively work to correct them. However, research has shown that readers are often unable to employ such metacognitive skills and are not good at assessing the actual state of their own knowledge. For example, a number of studies have shown that readers tend to overestimate their understanding of a given text. This phenomena is often refer to as "The Illusion of Knowing" (Glenberg et al, 1982, 1987). For example, Glenberg et al (1982) found that the correlation between subjects' self-assessment of their comprehension and their actual comprehension performance is very low. In other words, readers believe they have understood the text, but their performance on comprehension tests suggests otherwise. Clearly, understanding is the most complex and difficult form of explicit learning, requiring considerable mental effort on the part of the learner. Consequently, learners often utilise less effective learning strategies such as memorisation.

Learning as memorisation

Learning as memorisation results in the accumulation of information in long term memory. Information can be stored in memory in one of two-ways. First, the new material can simply be tacked onto memory without making any connection with the learner's pre-existing knowledge by the use of simple memory techniques such as repetition and rehearsal. Or, a link can be made between the new information and pre-existing knowledge. This is achieved by the use of more sophisticated memory techniques, such as organising the information according to some principle, or by the use of deep semantic processing as shown by the levels of processing approach.

However, learning as memorisation lacks the evaluative component of understanding, because no attempt is made to change or update either the new material or the learner's pre-existing knowledge (Stevenson and Palmer, 1994).

Thus understanding results in more meaningful learning, but because of its difficulty learners often engage in memorisation activities. Indeed, a study conducted by Spring (1985) has shown that learners frequently tend to engage in memorisation activities during reading at the expense of conceptual understanding. Spring identified two groups of first year college students as good and poor readers. Each group was asked to complete a reading strategy questionnaire consisting of statements describing study strategies, such as verbal rehearsal, which correspond to learning as memorisation, and statements describing comprehension strategies, such as relating the information presented in the text with pre-existing knowledge, which corresponds to learning as understanding. Spring found that good learners reported using understanding strategies to a greater extent than poor readers, who tended to use memorisation strategies.

The types of learning strategies people adopt during reading, such as memorisation and understanding, will ultimately affect the quality and durability of any subsequent learning. According to Kintsch and van Dijk's (1983) model, understanding or comprehending a text occurs at two levels, the propositional text base (a surface representation of the semantic structure of the text) and the situational model (a representation of the situation or events described by the text). The next sections will describe how these two mental representations are developed, but first it is necessary to expand on the important distinction between memory for text and learning from text.

Learning from text versus memory for text

To simply remember a text, means that we can reproduce the text to some extent, that is, we can remember specific sentences or perhaps the gist of the text. Learning from text however, means that we can use the information presented in the text, coupled with pre-existing knowledge to solve novel problems or make inferences. As such, learning from text requires conceptual understanding. Readers must integrate the new information they encounter with their pre-existing knowledge, and in turn, modify and update their pre-existing knowledge with the new information. To be able to remember a text, requires a minimal amount of processing. Readers need only have processed the text at a superficial level. To understand or learn from text requires a much deeper level of processing. The next section examines the processes underlying memory and understanding of texts using Kintsch and van Dijk's (1983) model of text comprehension.

The Kintsch and van Dijk model of text comprehension

As a text is read its component propositions are linked together to form a hierarchically structured textbase. The construction of the textbase depends upon the order in which the propositions in the text are encountered. According to Kintsch and van Dijk's model, there is a limit on the number of propositions that can be held active in working memory at any one time. Generally, readers keep active the propositions than have most recently been processed, where they can be combined with new incoming propositions. However, difficulties can arise if the reader encounters propositions that are not semantically related to those held in working memory, for example, when a topic shift occurs. In such cases the reader must make a bridging inference to link the two propositions together; such inferences are difficult to make, especially if the reader is unfamiliar with the subject matter of the text. Consequently, these gaps in the coherence of the text may be left unfilled and comprehension will suffer.

Britton and Gulgoz (1991) have demonstrated the role of coherence in text comprehension. They created two versions of a text on the air war in Vietnam, in which they identified several locations in the text where the reader would have to make bridging inferences in order to maintain coherence. In one version of the text the relevant bridging inferences were inserted for the reader. In the other version they were omitted. The results show that subjects with low prior knowledge of the text demonstrated significantly better recall and a superior mental representation of the completed text, where the bridging inferences were provided, than those who had read the original version.

The textbase can support a number of activities. Readers can recall the text, verify statements they have read, answer questions about the text, and summarise the text. However, knowing a text at this level does not necessarily mean that the reader has understood the text (McNamara, Kintsch, Butler-Songer, and Kintsch, 1996). For example, Moravcsik and Kintsch (1993) have found evidence to suggest that it is possible to remember a text without being able to use the information presented in the text productively. In order for the reader to acquire a deeper understanding of the text which is less susceptible to the ravishes of time, the reader must actively engage in the processing of the material and develop an adequate situational model.

According to Kintsch (1994), the formation of the situational model requires two things, active inferencing and prior knowledge. The reader must integrate the new information they encounter in the text with his or her pre-existing knowledge. This process helps readers make inferences about texts and apply what they have learned from the text to novel situations.

A vast research effort spanning several decades has focused on the identification of text characteristics which help to facilitate the construction of a coherent mental representation of text, at both the level of the textbase and situational model. We have already commented on the importance of text coherence in comprehension. Readers, especially those who are unfamiliar with the subject of the text demonstrate better comprehension with texts that are fully coherent as demonstrated by Britton and Gulgoz (1991). There are a number of ways in which authors can maintain coherence at both a local and a global level. At a local level in order for readers to make connections between ideas or concepts, the propositions that express them should appear in close proximity (Charney, 1994). At the global level, key concepts should be introduced early with the use of an informative title or overview (Kieras, 1980), and should be further developed and referred to throughout the text (van Dijk and Kintsch 1983; Thuring, Hannemann, and Haake 1995).

Research has also shown that readers expect texts to conform to certain types or genres. Kintsch postulates that readers gain through experience, schemata, which aid text comprehension by enabling the reader to predict the probable organisation of a particular text. For example, readers may possess schemata for newspaper articles, stories, or academic papers. The reader recognises the text type and then instantiates their schema for that particular genre. The schema is then used to help them make inferences, integrate the new information with their existing knowledge, and anticipate what will happen next. Just and Carpenter (1987), also point out that readers rely on schemata to help them identify the most important parts of the text, and therefore, where to direct most of their attention during reading. Studies by Kintsch and Yarborough (1982) and Dillon (1991) have demonstrated that articles that are written in a way that conforms to the schemata result in the reader forming a better understanding of the main ideas or gist of the text, than articles which do not conform to the schemata for that particular text type.

However, although simplifying the comprehension process may help the reader to construct a coherent textbase, it may hamper the development of an adequate situational model, because the reader will not have actively engaged in processing the text, integrating the new information with their pre-existing knowledge structures. Kintsch (1994) has suggested that learning might be facilitated by forcing the reader to process the text more actively.

Enhancing meaningful learning through active processing

In the past, a major focus of learning research was to identify ways in which we may enhance both the speed and ease of learning. However, research reported in Schmidt and Bjork (1992) suggests that variables which serve to maximise performance during acquisition can be detrimental for long term retention and transfer. They suggest that long term retention and transfer may be increased by creating difficulties for the learner during acquisition such as contextual interference. Contextual interference involves changes in the training or learning context, including changes in the task, practice schedules, or the amount of processing required from the learner. Schmidt and Bjork, (1992) argue that coping with such changes demands greater cognitive processing which can enhance learning. Research conducted by Battig (1979) has demonstrated that forcing learners to overcome high levels of contextual interference during acquisition leads to poor performance during acquisition but enhanced retention and transfer for both cognitive and motor tasks. Battig suggests that a variety of processing strategies have to be used to overcome contextual interference, and that learning or training under conditions of high contextual interference leads to more elaborate processing which enhances retention and facilitates retrieval. The effects of contextual interference have also been demonstrated by Mannes and Kintsch. 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 was superior in the different organisation group.

With respect to reading, Kintsch (1994) suggests that one way to induce active processing is to modify the coherence of the text. A fully coherent text in which the relationships between arguments are expressed in a clear, explicit way will require the reader to make very few, if any, cognitively demanding bridging inferences, and so reduce the amount of active processing. Conversely, a text in which the coherence is disrupted will force readers' to engage in more inferential activity, drawing on their prior background knowledge to interpret the incoming text, which may lead to superior learning. Thus learning may be improved because active processing leads to the formation of more links between the incoming text and the readers' pre-existing knowledge structures.

Kintsch suggests that text coherence may be disrupted by failing to specify some coherence relations so that the reader must infer them, omitting certain elaborations in the text, or not clearly signalling the macrostructure of the text. Kintsch is not suggesting that texts should be purposely disorganised or too difficult for even the most diligent reader. What he is suggesting is that learning may be enhanced if the reader has to actively process the material. Obviously, such texts would be extremely difficult for readers who lack background knowledge of the subject matter of the text. Indeed, Kintsch acknowledges that readers who lack adequate background knowledge will benefit more from a fully coherent and well organised text as was demonstrated in the Britton and Gulgoz (1991) study. However, more knowledgeable readers may benefit from the active processing required by such texts.

A number of studies have demonstrated that text induced active processing can be beneficial for learning. For example, Eileen Kintsch (1990) has found that knowledgeable and skilled readers produced better summaries of a poorly organised text than of a well organised text, presumably because they had to engage more actively with the disorganised text in order to extract its meaning. More recently, McNamara et al (1996) examined the role of active processing with children aged between 10 and 15 years. Half of the subjects were classified as having high background knowledge of the subject of the experimental text, the other half were classified as low knowledge readers. Four versions of the same text were used: (a) a text maximally coherent at both the local and macrolevel, (b) a text minimally coherent at the local level but maximally coherent at the global level, (c) a text maximally coherent at the local level but minimally coherent at the macrolevel, and (d) a text that was minimally coherent at both the local and macrolevel. McNamara et al, found that low knowledge readers benefited most from a fully coherent text at both the local and macrolevel. High knowledge readers, however, benefited most from the text that was minimally coherent at both local and macrolevel. McNamara et al, concluded that high knowledge readers benefited most from the minimally coherent text because it required them to process the material more actively, using their prior knowledge to generate inferences. They, also suggest that the results show that although high knowledge readers are capable of actively processing easy texts they are less likely to engage in active processing when the text is easy. Taken together these results seem to indicate that although there may be benefits from active processing for knowledgeable readers. Readers with low prior knowledge benefit more from a fully coherent text.

Summary

There are two distinct types of human learning; implicit and explicit. Implicit learning occurs without conscious control and results in knowledge that is itself implicit and cannot be easily described. Explicit learning, is deliberate purposeful learning. There are three kinds of explicit learning, problem solving memorisation and understanding. Understanding is the most difficult form of explicit learning because it places heavy demands on working memory and requires metacognitive awareness: the ability to reflect upon the state of one's own knowledge, recognise inconsistencies or knowledge gaps and actively work to correct them.

The distinction between memorisation and understanding is also apparent in the reading strategies people adopt and the subsequent mental representations of text that are formed. According to Kintsch and van Dijk's (1983) model, understanding or comprehending a text occurs at two levels, the propositional text base (a surface representation of the semantic structure of the text) and the situational model (a representation of the situation or events described by the text). The textbase can support a number of activities. Readers can recall the text, verify statements they have read, answer questions about the text, and summarise the text. The situational model corresponds to a deeper level of understanding, readers can make inferences about texts and apply what they have learned from the text to novel situations. Research into text comprehension has focused on ways in which comprehension process may be simplified for the reader. Indeed, a number of text characteristics have been identified that facilitate textbase construction. However, Kintsch (1994) suggests that the types of features that facilitate textbase development and memory for text are not good for long term learning. Recent work by McNamara et al (1996) suggests that making learning more difficult might enhance meaningful learning because it forces readers to engage more actively with the text. In terms of the distinction between understanding and memorisation made by Stevenson and Palmer, making learning more difficult could be said to force readers to adopt understanding strategies rather than memorisation.

3

Learning from hypertext

Overview

The merits of using hypertext materials in an instructional setting has 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. The aim of this chapter is to review some of the problems people may encounter when using hypertext for learning.

Hypertext and learning

Hypertext is of interest to educators for a number of reasons. First, it allows rapid access to vast amounts of information which in the case of hypermedia, can be stored in a variety of ways. Second, hypertext allows non-linear reading. The hypertext reader is not constrained to a single pre-determined route through the text. Instead, they are allowed to develop personalised paths through the document. Indeed, much of the hype about hypertext centres around its potential for learner driven exploration of a richly connected network of ideas. Third, hypertext greatly increases the amount of control the learner has of the learning situation, forcing them to make instructional decisions such as when to stop reading, what information to read, and perhaps more importantly in what order. Of the three factors described above, hypertext's non-linearity and potential for increased learner control are of most interest. The following sections examine these issues in more detail.

Hypertext versus text

Hypertext has been hailed as being a superior and more natural presentation medium than traditional linear text because it allows learners non-linear access to a network of facts and ideas. In other words, unlike traditional linear text which is thought to constrain the reader to a single pre-determined route through the document, hypertext allows readers to develop and follow personalised paths through the information.

Non-linear text is believed to facilitate learning because it is supposed to closely resemble the network organisation of information or knowledge in human memory. This idea is based on the assumption that knowledge is stored in memory as some kind of semantic network. However, as Charney (1994) points out, the proposed correspondence between hypertext networks and networked knowledge in human memory contradicts the psychological evidence about the organisation of information in memory. Moreover, there is little evidence to suggest that learners can understand information that is presented in network form any better than when it is presented in linear format.

The more fervent supporters of hypertext have tended to extol the virtues of non-linear text by way of a scathing critique of linear text, which they perceive to be a very restrictive medium, that forces readers to access information in a strongly directed and constraining fashion (Nelson, 1987; Jonassen, 1989; Collier, 1987). For example, Collier (1987) suggests that linear text is a "linear straitjacket of ink on paper". However, as Charney (1994) points out, the presentation of linear text as an organised succession of ideas, does not so much reflect the constraints of the printed medium, but more the needs of readers who rely upon the organisation of the text to help them form a coherent mental representation of the content.

Furthermore, although hypertext supporters might suggest otherwise, there is no hard and fast distinction between linear and non-linear text. Hypertext is after all, just another form of text, and non-linearity in text seems to be a matter of degree. Traditional linear text may contain a number of non-linear elements, such as footnotes, and keyword definitions. Moreover, although the physical layout of linear text is sequential, there is little evidence to suggest that people actually read text sequentially in a start to finish manner. For example, Dillon, Richardson and McKnight (1989) examined readers' use of journal articles. They identified three distinct reading strategies, of which only one could be described as linear. The other two strategies involved browsing and jumping through the text according to task demands, such as looking up references, or identifying the type of statistical analysis used. However, although hypertext might increase the amount of choice available to the reader in terms of the number of links they may follow and in the number of directions in which they may travel, it is important to note that the hypertext reader is never totally free, the network can never be wholly personalised because the hypertext author will have determined how the document will be linked, and the linking opportunities he/she provides may not suit each individual learner.

Effects of non-linear text

Non-linearity can be introduced into computerised text in a variety of ways, and to varying degrees, ranging from the addition of supplementary material such as a glossary, to multi-layered documents containing a large number of embedded text links.

One simple way of introducing non-linearity into computerised text is by the addition of glossaries or key word definitions, that are accessible via the main text screen. However, although studies have shown that readers are more likely to access ancillary material such as word definitions when using a computer than paper (Reinking and Rickman, 1990), there is evidence to suggest that even such simple non-linear excursions from the main text can disrupt the process of reading. For example Black, Wright, Black and Norman (1992) found that subjects were more willing to access definitions of unknown words when the definitions were displayed in the main text window than when they were presented in a separate glossary. Black et al suggested that the reason readers did not consult the separate glossary as often as the main text definitions, may have been because the jump to a new screen disrupted reading because subjects may have had difficulty establishing their previous position within the text before they made the jump.

Research has also shown that the consequence of a non-linear jump in terms of the type of information it causes to be displayed can also affect both discourse processing and the willingness of subjects to jump. Wright (1991) reports a study in which subjects could access on-line definitions that were presented either visually on screen or as digitised speech. Auditory presentation was used because the experimenters thought that it might help the readers by saving them from having to move their eyes away from the main text. However, the results showed that readers choose to re-read the text with greater frequency when the explanations were auditory than when they were visual. Wright suggests that some types of interaction with hypertext fits a dual task paradigm, in that the allocation of cognitive resources to one sub-task (supplementary explanatory material) detracts from performance on the main task (understanding the text).

Thus far, the focus of this section has been on quite simple forms of non-linearity in text. However, most hypertext systems generally involve more complex forms of non-linearity. Indeed, hypertext nodes can be linked to form a variety of non-linear structures. The complexity of these structures may have a number of effects on both reading and learning.

Non-linearity in text allows readers to follow their own paths through information. This aspect of non-linearity in hypertext has been picked up by Spiro, Feltovich, Jacobson and Coulson (1991) who developed the Cognitive Flexibility Theory of learning in ill-structured domains. Cognitive Flexibility Theory is a constructivist theory of learning which emphasises the complexity and interconnectedness of knowledge. The theory is based upon a set of principles to account for advanced learning in ill-structured domains such as social science. Spiro et al suggest that in order to gain advanced knowledge of ill-structured domains learners must engage in learning processes that afford greater cognitive flexibility. Such learning processes include "revisiting the same material at different times, in re-arranged contexts, for different purposes and from different conceptual perspectives" (p28). However, for learners to be able to develop cognitively flexible processing skills, flexible learning environments are required which permit the same items of knowledge to be presented and learned in a variety of different ways. Spiro et al suggest that non-linear hypertext systems may be an ideal platform because they have "the power to convey ill-structured aspects of knowledge domains and to promote features of cognitive flexibility in ways that traditional learning environments (textbooks, computer drill and practice) could not" (p24). Jacobson and Spiro (1991) designed a hypertext document according to the principles of Cognitive Flexibility Theory. They found that the system enhanced the transfer of learning across situations, whereas a computer based drill and practice program covering the same material improved memory for facts.

However, learners may experience a number of problems when using complex non-linear documents. Charney (1994) has identified a number of problems learners may encounter when trying to gather information in hypertext relevant to a particular learning goal. Given that the learner must first decide what information to focus on, he or she may never see the correct information because he or she may not be able to find it, or for some reason fail to select it. Second, even if the learner sees the correct information, he or she may see it at the wrong time. The timing of reading an information node could determine whether the learner judges it to be important. Third, there may be interference from the sheer amount of information viewed. Consequently, users may be unable to recognise which nodes have been visited, or which parts of the document remain to be seen. Finally, the learner may lose a sense of integrity about a given text, because he or she may be unaware of movements between two texts.

From Charney's summary it seems that there are three main problems with non-linear hypertexts. First, hypertext users have to bear the additional responsibility of managing their navigation through the system. Learners may be overwhelmed, confused, or disoriented by the sheer amount of choice offered by most hypertexts and encounter problems in establishing whether the information they require is available, and how to find it (Kim and Hirtle, 1995). These navigational difficulties may severely hinder the learning process. Tripp and Roby (1990) point out, learning may suffer because the hypertext reader will have fewer mental resources directed toward the learning task, because they will have to focus on orienting themselves within the hypertextual space. However, disorientation may also result in some positive learning outcomes. Mayes, Kibby and Anderson (1990a, 1990b) suggest that in certain circumstances disorientation may be a necessary pre-condition for conceptual understanding. They point to the example of discovery learning, in which the whole point of the instructional situation is that learners should engage in a continual process of integrating the new information with prior knowledge and modified and updating prior knowledge in the light of this new information As such Mayes et al concluded that disorientation or getting lost may be both a desirable and necessary part of the process of conceptual understanding.

Second, traditional printed texts generally incorporate a variety of discourse cues and signals that help the reader to extract the author's message. Hypertext however, may be structured in ways quite different to what the average reader might expect, and some of the standard discourse cues may not be present or are at least less obvious. This may severely disrupt the reader's ability to form a coherent mental representation of the text.

Third, by allowing the user to determine what information is read and in what order, the possibility that they will receive a choppy or fragmented exposure to the information is increased, and so too, is the likelihood that comprehension may be disrupted (Charney, 1994; Duchastel, 1990; Foltz, 1996; Rouet, 1992; Wright, 1991). As Foltz (1996) points out, the hypertext author may not be able to anticipate every link the reader might follow, therefore the coherence of the text may be disrupted. However, this factor might work either for or against the learner depending on their familiarity with the text. For example, recall the study conducted by Britton and Gulgoz (1991) described in chapter 2. They found that low knowledge readers demonstrated significantly better recall, and a more superior mental representation of a fully coherent text. High knowledge readers however, may benefit from a more difficult text because of the benefits that may be derived from text induced active processing as demonstrated by McNamara et al (1996). It may be therefore that hypertext's complexity might induce more active processing and thus lead to better learning at least in the case of learners who have prior knowledge of the text topic.

Hypertext research

The general findings of research studies that have examined both comprehension and learning in hypertext, seem to indicate that learners may indeed experience problems when using hypertext. For example, long term studies conducted by Kommers (1990) and Mandl, Hanniger and Schnotz (1991) found that hypertext presentation favoured more able students. A study conducted by Gordon, Gustavel, Moore and Hankey (1988) examined learning from linear text and hypertext. Two types of text were used, an expository general interest article and a technical report. Subjects were instructed to read the expository article as they would read any other general interest article. Subjects who read the technical articles were instructed to explicitly learn the material. After reading both a linear and hypertext version of the text to which they were assigned, subjects were asked to recall of as much of the text as possible, answer several questions about the text, and express their preferences for reading format. Gordon et al, found that subjects who read the linear texts remembered more of the basic ideas and assimilated more of the text's macrostructure than after reading in hypertext. Most students also preferred the linear presentation and perceived it as requiring less mental effort. The hypertext was most disruptive with the expository text type. For the technical article hypertext was less disruptive.

More recently, Foltz (1996) studied readers' comprehension and comprehension strategies using either a linear text or hypertext. Half of the subjects were instructed to find certain information in the text. The other half were instructed to read the text for general knowledge. After reading, the subjects answered multiple choice comprehension questions. Some of the questions required subjects to recall information from the text, others required them to apply what they had learned to new examples. Finally subjects wrote an essay about the content of the text. Foltz found that there were no differences between text formats for the amount of time it took subjects to read the text. The subject's comprehension was also equivalent for the different text formats, and there were no differences in the number of macropropositions generated in their essays, and there were no differences in subjects' scores on the short answer essay and the multiple choice questions.

However, as Charney (1994) points out, there are methodological problems with both of these studies which limit our ability to draw clear cut conclusions from them. In contrast to most real-world learning situations, the subjects in these studies knew that they had to read the whole text and that everything they needed to learn would be available in that text. The subjects also used a list from which they selected topics to read, or in the case of Foltz an interactive overview diagram, which is much simpler than having to make sense of a complex non-linear network of embedded text links. In addition, the texts used were quite small, the experimenters did not control for the effects of prior knowledge of the text topic, and both studies only measured short term learning. That is the learning measures were administered immediately after the subjects had read the experimental text, no long term measures of learning were used in either study.

Experiments 7, 8 and 9 presented in chapter 7 of this thesis re-examine the issue of learning in hypertext. In contrast to the experiments described above, these studies included measures of both short term and long term learning, using much longer non-linear texts with many embedded text links.

Learner control

Traditional forms of computer based instruction centred around programmed instruction and Artificial Intelligence techniques. The former is based upon behaviourist techniques, in which learning is thought to be best achieved via a process of shaping where behaviours that are correct or appropriate are reinforced. The latter includes approaches such as Model Driven Intelligent Tutoring which seeks to replicate one-to-one tuition. The system has a representation or model of the student's level of understanding which it uses to regulate the interaction. However, both of these approaches encounter problems with domains that are non-procedural, and fail to take into account the individual differences of the learner. One approach to adapting instruction to meet the individual needs of the learner, is to allow them greater control over the learning situation, in terms of the pacing of the instruction, the amount of practice, the number of examples worked through, and the sequencing of instructional events.

Many educators regard extended learner control as a positive step forward in the educational process, believing that learners should be actively engaged in finding things out for themselves, learning through experience rather than being passive recipients of knowledge (Papert, 1980). A number of quite ambitious claims have been made about the possible benefits that learner driven instruction might produce. It has been suggested for example, that learner control induces learners to become more actively engaged with the material under study (Caldwell, 1980) and increases the learner's motivation minimising the possibility that they may become bored or frustrated because they have the power to skip material they already believe they know, or do not wish to learn, in favour of information they consider to be more important (Carrier, 1984; Large, 1996; Schank, 1993; Stanton and Baber, 1992). Moreover, Merrill (1975) suggests that learner control encourages learners to learn how to learn. In other words, forcing the individual learner to make instructional decisions may help them develop learning strategies that may be used in different learning situations or for different learning tasks. However, these claims have largely been found to be unsubstantiated.

Hypertext and learner control

Previous studies on learner control have focused on the effects of allowing learners varying degrees of control over the amount of practice, or the sequencing of the information (McGrath, 1992). However, the possibilities for learner control are considerably increased with hypertext, especially in terms of allowing users to determine the sequence of instructional events. This ability to explore hypertext freely has been ascribed a number of desirable characteristics. It has been suggested that hypertext exploration may facilitate conceptual understanding and help learners see the connections between different reading sources more easily (Becker and Dwyer, 1994; Small and Grabowski, 1992; Spiro et al, 1996). Moreover, McAleese (1990) suggests that hypertext exploration can enhance both the learning of concepts and learning at the metacognitive level.

Learner control research

The research evidence on the effectiveness of learner control has yielded somewhat contradictory results. For example, Mayer (1976) investigated how experimenter controlled and subject controlled card sequences affected the ability of subjects to solve programming problems. Mayer found that although there was no overall differences between the sequences, there were differences in the types of programming problems subjects could solve. Those subjects who had chosen their own reading order were better able to solve novel types of problems, while those in the experimenter controlled condition were better at solving programs closer to those presented in the text. Mayer concluded that allowing subjects to choose their own reading order resulted in deeper encoding. Similarly, Gray (1987) examined the effects of allowing subjects to control the sequencing of instructional information. She found that learner control resulted in better comprehension of the text. However, these findings seem to be in a minority, a great many other studies have found that when learners are given greater control, especially in terms of the sequencing of information they perform poorly, or learn less well, in comparison to learners whose instructional format offers little scope for learner control. In general, learners make poor choices, stop reading too soon, are not very good at assessing the importance of information, and are unable to anticipate whether important information exists in the portions of the text they have not yet read (Charney, 1994; Goetzfried and Hannafin, 1985; Johansen and Tennyson, 1983; Kieras, 1985; Williams, 1993). For example, Goetzfried and Hannafin (1985) examined the effects of learner control on students' learning of a mathematics rule. They found that subjects in the learner control condition tended to quit the program early and demonstrated less efficient learning.

However, the use of learner control has also been shown to be affected by certain student characteristics such as ability and prior domain knowledge. Studies conducted by Ross and Rakow (1982) have shown that students of high ability perform better with learner control than low ability students. Research has also shown that learners who have prior background knowledge of the subjects of instruction do not in general, fare as badly as novice learners in situations of high learner control (Gay, 1986; Goetzfried and Hannafin, 1985; Lee and Lee, 1991; Nelson, 1985; Shin, Schallert and Savenye, 1994). For example, Gay, (1986) examined adult student learning from an interactive video disc. One group was allowed to control the sequence of learning, while the other group was under program control. Gay found that students with high prior knowledge of the content of the instruction were significantly more efficient in the use of their time than low prior knowledge students. This pattern of results has also been observed in children. Shin et al (1994), investigated the effects of learner control in hypertext on second-grade students (approximately 8 years of age) who had different levels of prior knowledge about the content. Half of the students were allowed free access to the materials, the other had only limited access. Shin et al discovered that students with high prior knowledge were able to function equally well with both conditions, whereas students with low prior knowledge could use the limited access system more effectively than the free access system. Students with low prior knowledge who used the free access system were more confused about what to do at the start of the program, often moved to a new topic without completing the current one, and quit the program before completing many topics. Experiment 9 (chapter 7) examines the effects of prior knowledge on adult learning in hypertext compared to linear text. The text used in this study is much longer than the text used by either Shin et al or Gay.

Problems with learner control

Clearly, transferring the responsibility for the management of learning from the computer or teacher to the individual learner is not without its problems. As Large (1996) points out, in situations of high learner control, the learner is not only concerned with learning, but is also responsible for making decisions about learning strategies. In other words, the learner must assess what is known, how many concepts have been mastered, and perhaps more importantly, what is not yet known. However, as pointed out in chapter 2, readers are often unable to employ such self reflective processes, or metacognitive skills. The use of metacognitive skills is particularly important in situations of high learner control, in which the learner often has to make important decisions concerning the sequencing of the material, and the amount of practice. As Rouet (1992) points out, all of these decisions require some level of awareness of the ongoing comprehension process. The failure of users to employ metacognitive skills may account for the poor performance of learners in situations of high learner control. For example, Garhart and Hannifin (1986) found that learners who fail to use comprehension monitoring strategies perform badly in situations of high learner control. Similarly, Young (1996) found that learners who use self-regulated learning strategies, perform better under learner control than learners who fails to employ such skills.

Finally, successful learning may ultimately depend upon the student's motivation to learn. There is evidence to suggest that increased learner control causes students to adopt a more positive attitude towards instruction (Kinzie and Sullivan, 1989), and that students often prefer to play a more active role in the management of their own learning (Ross, Morrison and O'Dell, 1989). On the face of it, there appears to be a strong intuitive appeal in allowing students to choose the methods of instruction they favour. However, although these studies found that subjects preferred learner control to program control, it did not lead to any performance gains in terms of the amount of material actually learned. Previous research has shown that performance under a preferred mode may lead to lower achievement than participation in a less preferred mode (Carrier, 1984; Tobias, 1972). For example, Tobias (1972) found that college students who were allowed to chose between overt and covert response styles in a programmed instruction lesson did not benefit when assigned to the version of their choice. Similarly, Peterson and Janicki (1979) asked sixth grade students to indicate their preference for small or large group instruction. When students were assigned to either their preferred or non-preferred condition, Peterson and Janicki found that their performance was worse in the condition of their choice. Snow and Peterson (1980) explain this phenomena by arguing that students often prefer methods of instruction that they think will require less work, concentration and time. As Jaynes (1989) has pointed out, most learners have little time and less interest in exploration: they want to be led.

In terms of hypertext, there isn't a great deal of research evidence regarding the effects of control on the learner's attitudes towards instruction hypertext. Small and Grabowski (1992) found that three motivational factors (interest, importance and self confidence) increased as a result of using hypertext for learning. However, Small and Grabowski failed to compare performance on hypertext with a linear control. This severely limits our ability to draw clear cut conclusions from their data. More recently, Becker and Dwyer (1994) found that students who had used hypertext were more self determined and had higher levels of overall intrinsic motivation, as measured by the Motivated strategies for Learning Questionnaire MSLQ than students who had used a traditional linear text. However, there was no overall improvement in performance in terms of the amount learned between subjects in the hypertext and linear conditions.

Clearly there is a need to examine how preference for instructional format interacts with actual performance. Experiment 10 (chapter 8) attempts to fill this gap in the research evidence by using a repeated measures design in which subjects use both a linear text and a hypertext and in which both qualitative measures of the subjects' preference for the text format, (high and low control) as well as quantitative performance measures on learning tasks were obtained.

Assisting hypertext users

Given the problems associated with learner control and the use of hypertext systems for learning there seems to be a need for tools that may support learning. As mentioned earlier, one way to help readers overcome the possible negative effects of disorientation is to provide navigational aids that work by allowing readers to review and preview their progress through hypertext. Indeed, research has shown that navigational aids such as spatial maps and textual contents lists can help to eliminate some of the navigational problems typically experienced by hypertext users (see for example, Monk, Walsh, and Dix, 1988; Simpson and McKnight, 1990; Gupta and Gramopadhye, 1995).

Given that such aids can help to reduce disorientation, it seems reasonable to suggest that they might also facilitate learning in hypertext. This is because the load of navigation would be considerably reduced, thus freeing up more of the learner's valuable working memory resources for the task of learning. It may also be the case that the provision of a map may help to increase the local coherence of the text (Thuring, Hannemann and Haake, 1995). Indeed, Thuring et al, suggest that a link between two nodes on a map can be regarded as fulfilling a function analogous to a conjunction in a linear text.

Unfortunately, the research evidence is inconclusive. While Dee-Lucas and Larkin (1995) found that both the use of a map and a contents list led to better memory for text topics, and better breadth of recall compared with a no aid text, Wenger and Payne (1994) found that the provision of a spatial map had no effect on subjects' comprehension of hypertext. Similarly, Stanton, Taylor and Tweedie (1992) found that the inclusion of a spatial map resulted in poor performance on a sentence completion task, less use of the system in terms of following secondary links, and lower perceived control over the system. Thus there is a clear need for more experimental work in this area. Experiment 11 presented in Chapter 9 aims to fill this gap in the existing literature by examining the effects of two navigational aids, the spatial map and textual contents list on learning in hypertext

However a number of writers suggest that maps may not be suitable learning aids. Although navigational aids such as contents lists, and spatial maps in particular appear to foster efficient navigation, efficient navigation may not be a prerequisite of efficient or effective learning. As Dee-Lucas (1996) points out, the better, more accurate navigation that arises from the use of a map, may also result in less breadth of learning by reducing the range of information read. That is, readers will be more likely to travel directly to target information and so neglect to view related but non-target nodes. Moreover, the information presented by these aids only depicts structural relationships; they say little about the conceptual structure of the text, and so are in themselves unlikely to foster conceptual understanding.

As pointed out above, one of the limitations of navigational aids, such as a map, is that they merely represent the structural layout of the document. That is, they only show which nodes are related to each other. They say nothing about this relationship or why it exists. As such, they are unlikely to foster conceptual understanding. What seems to be needed, therefore, to improve learning from hypertext is an aid that facilitates conceptual understanding of the text, not one that simply facilitates finding the location of information. We therefore constructed such an aid, which we called a conceptual map. In contrast to a spatial map which simply depicts the structural properties of a document, a conceptual map identifies the key concepts in the text and specifies the relations between them. Experiment 12 examines the effectiveness of a conceptual map compared to a spatial map in supporting learning in hypertext.

Summary

The characteristics of hypertext that are of most interest to educators are the same characteristics that can promote difficulties for the learner. Specifically, learners may experience navigational problems in hypertext and the multitude of links that can be found in many hypertexts may in fact disrupt the coherence of the text which can in turn hamper the comprehension process. However, both of these factors may work for and against the learner. That is, the difficulties hypertext introduced might enhance learning because the reader has to work harder and engage more actively to construct meaning from the text. The aim of experiments 7, 8, 9 and 10, presented in this thesis was to examine this issue in more detail. Specifically, these experiments seek to examine whether good or efficient navigation is a pre-requisite of meaningful learning. To that end, these studies examined both navigation and learning in non-linear hypertext compared to a linear version of the same document. Experiments 11 and 12 examined the effects of navigational aids on both navigation and learning in hypertext.

4

Disorientation in hypertext

INTRODUCTION

The aim of experiments 1, 2 and 3 was to examine the problem of disorientation in hypertext empirically, and to identify the conditions which appear to lead to its occurrence. Experiment 1 served as a pilot study; therefore only a small number of subjects were tested. The study examined the effects of two hypertext topologies (hierarchy and non-linear) on navigation performance compared to a linear version of the same document. The experiment was similar in design to that of McKnight et al (1990). It was expected that the performance of subjects in the linear condition would be superior to that of subjects in the hierarchy and non-linear conditions. In turn it was also expected that subjects using the hierarchically structured document would perform better than those using the non-linear hypertext.

Disorientation while browsing can lead the browser to miss out sections of the text and open the same few cards repeatedly (McKnight et al 1990; Simpson and McKnight, 1990). This is thought to occur either because subjects believe they have seen the whole text or because they are unable to find the information they require. For this reason the number of cards opened during browsing, the number of cards repeatedly opened and the subjects' estimates of the document's size were measured.

The effects of disorientation on navigation, can lead to an increase in the time it takes users to locate information and cause users to follow a less than optimal route through the document (Leventhal et al, 1993; Rada and Murphy, 1992). It may also affect their ability to extract information from the text relevant to an information retrieval task (Edwards and Hardman, 1989; Mohageg, 1992). Therefore, the time it took subjects to retrieve information, the directness of their chosen route to the information, and the accuracy of their response to an information search task were measured. In addition, the subjects' evaluation of their performance was evaluated with the use of a post test questionnaire.

The aim of experiment 2 was to replicate the results of experiment 1 with a larger group of subjects, who were unfamiliar with the concepts and ideas presented in the experimental text. The subjects used in experiment one were all postgraduate psychology students. It may be that their background knowledge of the text could have influenced their performance It was therefore necessary to examine the effects of the hypertext topologies on subjects with little or no background knowledge of the text. The study was an exact replication of experiment 1; therefore, the same predictions apply.

Experiment 3 also examined the effects of two hypertext topologies (hierarchical and non-linear) on navigation performance compared to a linear version of the same document. Experiment 1 and 2 examined disorientation in hypertext with the use of a question answer task. Subjects were given ten questions, and they searched through the hypertext to locate the answers. Each time a subject made a response they were returned automatically to a "start screen" and were given the next question to answer. Consequently, subjects always started their search from the same point in the document, and had followed a well trodden path each time they searched the document. However, in everyday usage, it is more likely that users would start a series of searches from within the text rather than being returned to a start screen each time. Therefore experiment 3 examined the effects of allowing subjects to start their searches from within the hypertext document. This measure will more accurately assess the subject's level of knowledge of the hypertext's structure. The same performance measures were taken as in experiments 1 and 2. In addition, one common problem with hypertext is that users often become distracted. For example, they may become side-tracked by an interesting digression or the telephone might ring, distracting their attention. Therefore, it is essential that users should be able to pick up from where they left off. Thus, subjects' performance is also compared before and after a distraction period in order to assess whether the subjects have enough knowledge of the system structure to re-gain their bearings after a filled delay. It was predicated that the best performance will result with the linear text, next best with the hierarchical hypertext and next best with the non-linear hypertext.

Previous research by Campagnoni and Ehrlich (1989) has shown that subjects with good visualisation skills demonstrate more efficient navigation performance than subjects with poor visualisation skills. Therefore the relationship between spatial ability and navigation performance was examined in all three studies.

EXPERIMENT 1

METHOD

Subjects

Twelve postgraduate students participated in the study, 5 males and 7 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 Stevenson (1993) and "Learning: Principles, Processes and Practices." by Stevenson and Palmer (1994). The text was adapted for use in hypertext format by the present author in collaboration with Rosemary Stevenson. 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 node in the stack to be displayed.

The nodes 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 node bearing the same name as the button to be displayed. The document also included a backtrack facility.

The nodes in the non-linear document were linked to form a network based on a number of cross referential links, in which any node could be connected to any number of other nodes. 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 user's exploration, whereas the non-linear structure is essentially formless, and exercises no control over the user's 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. A considerable amount of time, care, and attention was invested in the construction of the text to ensure that it flowed smoothly irrespective of the order in which the nodes were accessed.

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. A copy of the text can be found in appendix A.

Design

The experiment used a between subjects single factor design. The independent variables were hypertext topology, hierarchical, non-linear and linear. The dependent variables included measures of browsing and navigation. The browsing measures were: the subjects' estimate of document size, and the number of cards opened during browsing. The navigation measures were: the mean time to answer questions, accuracy, and the mean number of additional nodes accessed per question.

Each subject was randomly assigned to one of the three experimental conditions. Subjects were required to read through the hypertext until they thought they had read the whole document, they were than asked to estimate the size of the document in approximate number of cards. The subjects then used the document to find the answers to ten questions. After a distraction period, they returned to the document to locate a further five cards. Finally subjects completed a post-test questionnaire.

Procedure

After initial tuition on how to use the hypertext document, 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. Subjects then used the document to locate the answers to 10 questions. For example, *Who proposed the pragmatic model of analogical thinking?* The answers to the questions could be found in specific cards in the document. Subjects were instructed to navigate through the hypertext document taking the most direct route possible 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 ten 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. The subjects' 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. They were then taken back to the hypertext to complete a further search task

Specifically, subjects were instructed to navigate through the hypertext in order to locate 5 target cards. This measure was incorporated to assess whether the subjects had enough 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. A full list of the navigation questions and the five target nodes used in this experiment can be found in Appendix D.

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.

Items were written to measure both disorientation and learning. The questionnaire was then piloted using a sample of 50 undergraduate students at the university of Durham. The data collected in the pilot study, were then subjected to an item analysis and a factor analysis in order to select the best items for the final version of the questionnaire.

Each item was correlated with the total score for the relevant scale: disorientation and perceptions of learning. The second column of Tables 4.1 and 4.2 present the item total correlations for the disorientation and perceptions of learning scales respectively. The higher the correlation between the item and total score, the more reliable the item. The results of the item analysis for the disorientation scale suggest that those items with correlations lower than 0.5 (items 9, 10, 12, and 13) should be discarded. The results of the item analysis for the perceptions of learning scale suggest that those items with correlations lower than 0.5 (items 5, 6, 9, and 10) should be discarded.

Table 4.1

Correlation coefficients for the item analysis of the disorientation scale and factor loadings for the varimatrix rotation of items for the disorientation scale.

Item	Correlation coefficient for item analysis	Loading on Disorientation factor
1. *I wasn't sure where to go*	0.91	0.93
2. *I often felt lost*	0.88	0.93
3. *I could easily find my way out of the system*	0.83	0.73
4. *I kept on going round in circles*	0.76	0.83
5. *I understood how the document was structured*	0.76	0.84
6. *I kept track of my movements*	0.88	0.89
7. *I could easily re-orient myself after a distraction*	0.91	0.95
8. *I always knew my position in the document*	0.89	0.83
9. *I understood how the document was structured*	-0.09	-0.23
10. *I often felt confused*	0.23	
11. *I reached my destination purely by chance*	0.78	0.69
12. *I had seen all the available information*	0.14	0.057
13. *There was too much choice*	-0.20	-0.31
14. *I often forgot why I had followed a link*	0.71	0.66

As an added measure the items were also subjected to a simple structure, principal components factor analysis, using a varimatrix rotation. The third column of Table 4.1 and 4.2 present the factor loadings for the disorientation and perceptions of learning scales respectively. Those items with the highest loading on factor 1 (disorientation or perceptions of learning) were chosen. The results of the factor analysis confirmed the selections made using item analysis.

Table 4.2

Correlation coefficients for the item analysis of the perceptions of learning scale and factor loadings for the varimatrix rotation of items for the perceptions of learning scale.

Item	Correlation Coefficient	Loading on perceptions of learning factor
1. *The text was too difficult*	0.63	0.60
2. *I could easily summarise the text*	0.79	0.92
3. *I felt I had understood the material*	0.84	0.89
4. *I felt comfortable selecting my own reading order*	0.85	0.84
5. *The text was confusing*	0.19	
6. *The links often confused me*	0.37	0.12
7. *I would have preferred to have more guidance*	0.78	0.79
8. *I would be happy to use this type of text for my own personal study*	0.72	0.65
9. *I liked having more control*	0.41	0.17
10. *I found it helpful to be able to chose for myself which information to read*	0.39	0.15
11. *The amount of choice was confusing rather than helpful*	0.69	0.65
12. *I could explain the gist of the text to a third party*	0.82	0.86
13. *I would have preferred the text to be presented as a book*	0.85	0.72
14. *Given the choice I would not use this type of text again*	0.56	0.54

Finally, measures of internal consistency and reliability were taken. To estimate the internal consistency of the two scales coefficient alpha (Cronbach, 1951) was determined. For the disorientation scale alpha = 0.96, for the perceptions of learning scale alpha = 0.93. The reliability of the questionnaire was assessed using the Guttman Split halves technique. For the disorientation scale the Guttman split halves reliability was 0.96, and for the perceptions of learning scale 0.91.

The final questionnaire consisted of twenty items 10 for each scale. Half of the items were positive in tone the remaining were negative in tone. 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

Browsing

Number of cards opened

The number of cards opened by each subject during the reading phase was recorded. The top row of Table 4.3 presents the mean number of cards opened for each condition.

Table 4.3
Mean number of cards opened during reading, and the mean estimate of document size for experiment 1

	Linear	Hierarchy	Non-Linear
Mean number of cards opened	45.8	37.3	28.8
Mean estimate of document size	42.4	35.9	25.1

A one-way ANOVA revealed a significant effect of subject group ($F(2,9) = 34.1$, $p < 0.001$). Tukey HSD tests indicated significant differences between each condition. (linear vs. non-linear: $Q\ (3,9) = 13.2\ p < 0.01$; linear vs. hierarchy: $Q\ (3,9) = 5.8\ p < 0.05$; hierarchy vs. non-linear: $Q\ (3,9) = 7.4\ p < 0.05$).

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 4.3 represents the mean estimate of the document's size for each condition. A one-way ANOVA revealed a significant effect of subject group ($F\ (2,9) = 4.8$, $p < 0.05$). Tukey HSD tests indicated significant differences between the linear and the non-linear condition only ($Q\ (3,9) = 4.3$, $p < 0.05$). 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.

Navigation

Accuracy in answering the questions

The number of questions each subject answered correctly was recorded. Each subject achieved the maximum ten points, across the three conditions.

Time taken to locate the answers to the questions

The total time taken to answer the 10 questions using the hypertext document was calculated for each subject. The top row of Table 4.4 presents the mean time taken to locate the answers to the 10 questions for each condition.

Table 4.4
Mean time taken and the mean number of additional cards opened to locate each answer for experiment 1

	Linear	Hierarchy	Non-linear
Mean Time (in seconds)	75.6	86.2	100.7
Mean number of additional cards	1.2	7.8	11.3

A one-way ANOVA revealed a significant effect of subject group (F (2,9) = 33.5, $p <$ 0.01). Tukey HSD tests indicated significant differences between all three conditions. (linear vs. hierarchical: Q (3,9) = 4.9, $p < 0.01$; linear vs. non-linear: Q (3,9) = 11.5, $p <$ 0.01; hierarchy vs. non-linear: Q (3,9) = 6.7, $p < 0.01$). Subjects in the linear condition answered the questions significantly faster than subjects in the hierarchical condition, who in turn responded faster than the subjects in the non-linear condition.

Number of additional cards opened to locate each answer

The number of additional cards opened by each subject to locate the answers to the ten 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 bottom row of Table 4.4 presents the mean number of additional cards opened for each condition .

A one-way ANOVA revealed a significant effect of subject group (F (2,9) = 34.9, $p < 0.01$). Tukey HSD tests indicated significant differences between all three conditions. (linear vs. hierarchical: Q (3,9) = 7.6, $p < 0.01$; linear vs. non-linear: Q (3,9) = 11.6, $p < 0.01$; hierarchical vs. non-linear: Q (3,9) = 4.1, $p < 0.05$). 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.

Time taken to locate the 5 target cards

The total time taken to locate the 5 target cards using the hypertext document was calculated for each subject. The top row of Table 4.5 presents the mean time taken for each condition.

Table 4.5
Mean time taken and the mean number of additional cards opened to locate the 5 target cards for experiment 1

	Linear	Hierarchy	Non-linear
Mean Time (in seconds)	77.7	107.2	115.6
Mean number of additional cards	2.3	7.9	12.7

A one-way ANOVA revealed a significant effect of subject group (F (2,9) = 35.0, $p < 0.01$). Tukey HSD tests indicated significant differences between the linear vs. hierarchical condition (Q (3,9) = 8.8, $p < 0.01$), and the linear vs. non-linear condition only, (Q (3,9) = 11.3, $p < 0.01$). Subjects in the linear condition located the five target cards significantly faster than the subjects in both the hierarchical and non-linear conditions. Although subjects in the hierarchical condition located the cards faster than subjects in the non-linear condition, the difference between these groups was found not to be significant.

Number of additional cards opened to locate the 5 target cards

The number of additional cards opened by each subject to locate the 5 target cards was calculated. The bottom row of Table 4.5 presents the mean number of additional cards opened for each condition.

A one-way ANOVA revealed a significant effect of subject group (F (2,9) = 33.1, $p < 0.01$). Tukey HSD tests indicated significant differences between all three conditions. (linear vs. hierarchical: Q (3,9) = 6.3, $p < 0.01$; linear vs. non-linear: Q (3,9) = 10.5, $p < 0.01$; hierarchical vs. non-linear: Q (3,9) = 5.2, $p < 0.05$). 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 4.6 presents the total scores per condition for the disorientation scale, and the bottom row for the perceptions of learning scale.

Table 4.6
Mean scores on the disorientation and perceptions of learning scales for experiment 1

	Linear	Hierarchy	Non-linear
Disorientation Scale	64.8	27.5	18.0
Learning Scale	25.0	13.5	11.5

The questionnaire data was 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 ($H = 9.9$, $df = 2$, $p < 0.05$). Analysis of the perceptions of learning scale also revealed a significant difference ($H = 7.8$, $df = 2$, $p < 0.05$).

Further analysis of the disorientation scale using Mann-Whitney tests revealed significant differences between scores for all three groups. (linear vs. non-linear: U = -2.3, p <0.05; linear vs. hierarchy: U = -2.3, p <0.05; hierarchy vs. non-linear: U = -2.3, p<0.05). 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 hierarchical 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, (U = -2.32, p<0.04), and between the linear and hierarchical conditions (U = -2.3, p <0.05) only. Perceptions of learning in the linear condition were more positive than those in either the hierarchical or the non-linear conditions.

Spatial Skills

The subjects' performance on the spatial skills test administered during the distraction period was correlated with subjects' performance on the navigational measures. The results showed that for subjects in the linear text condition the correlation between spatial ability and navigation performance was found not to be significant (r = 0.08, p < 0.92). However, for subjects in the hierarchical and non-linear conditions the correlation between spatial ability and navigation performance was found be significant (hierarchy: r = -.96, p < 0.04; non-linear: r = -.96, p < 0.04). Thus, as the subjects' scores on the spatial skills inventory increased the number of additional cards opened during navigation decreased. Therefore spatial ability was found to be positively correlated with navigation performance in hypertext.

DISCUSSION

On all measures, except accuracy in answering the questions, performance on the linear text was significantly better than performance on the non-linear text, while performance on the hierarchical text fell between these two extremes. 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 has having learnt more from the interaction period, and as having experienced fewer navigational problems than subjects who had used the non-linear text. Ratings of subjects using the hierarchical text fell between these two extremes.

The results for the browsing 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, 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, Dillon, and Richardson, (1991). 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 these findings, their data also showed that subjects using the hypertext tended to overestimate the document's size. However, the discrepancies in the findings of this 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 three minutes 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 this 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, in this study, 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 non-linear document, 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 number of additional cards opened by subjects during the questions answer task was also correlated with the subjects' score on the spatial sub-scale of the AH5 test. The results showed that for subjects in the linear condition there was no relationship between spatial ability and navigation performance. However, for the hierarchical and non-linear conditions the results show that spatial ability is correlated with navigation performance. That is, subjects with high spatial scores open fewer additional cards than subjects with low spatial scores. These results support those of Campagnoni and Ehrlich (1989) who also found that subjects with good spatial skills demonstrated more efficient navigation performance. The results further suggest that while spatial skills do not influence the ease with which readers find answers to questions in a standard linear text, they do affect the answering of questions in hypertext. Thus, spatial ability appears to be a good predictor of navigation performance in hypertext.

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. Navigation performance for the hierarchical and non-linear conditions in terms of the number of additional nodes opened during the search task also seems to be related to individual differences in subjects' spatial ability. However, these results must be interpreted with some caution, as only a small number of subjects were tested. In addition, all of the subjects were familiar with the subject matter of the experimental text, and this may have affected their performance, especially in terms of question answering. It is therefore necessary to examine the effects of text structure on the performance of novice subjects who are unfamiliar with the text.

EXPERIMENT 2

METHOD

Subjects

Fifty four undergraduate volunteers from Durham University served as subjects and were paid for their participation. Their ages ranged from 18 to 31 years. All subjects had some previous experience of using computers. Each subject was tested individually. At the start of the experiment subjects were unfamiliar with the concepts and ideas presented in the text.

Materials

The same experimental materials were used as in experiment 1 (pilot study). However, in order to reduce the time it took to run the experiment, the length of the text was reduced from 4500 words to 3600 words, although the document still contained 45 cards.

Design

The experiment used the same design as in experiment 1.

Procedure

The experiment followed the same procedure as experiment 1, with the exception that the spatial scale of the NFER Nelson General Ability Scale was used instead of the AH5 test. A full list of the navigation questions and the five target nodes used in this experiment can be found in Appendix D.

RESULTS

Browsing

Number of cards opened

The number of cards opened by each subject during the reading stage was determined. The top row of Table 4.7 presents the mean number of cards opened per condition for the reading stage.

Table 4.7

Mean number of cards opened and mean estimate of document's size for experiment 2

	Linear	Hierarchy	Non-Linear
Mean number of cards opened	42.4	25.1	21.1
Mean estimate of document size in cards	40.1	32.4	18.8

A one-way ANOVA revealed a significant effect of subject group. ($F(2,51) = 51.2$, $p < 0.001$). Tukey HSD tests indicated significant differences between the linear condition and the other two text conditions. (linear vs. non-linear: Q (3,51) = 13.5, $p < 0.01$; linear vs. hierarchical: Q (3,51) = 10.9, $p < 0.01$; non-linear vs. hierarchical: $Q(3,51)$ $p < 1$).

Estimate of document size

After the reading stage, 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 4.7 presents the mean estimate of the document's size for each condition. A one-way ANOVA revealed a significant effect of subject group. (F (2,51) = 17.1, $p < 0.001$). Tukey HSD tests indicated that subjects in the non-linear condition significantly underestimated the size of the document in comparison to subjects in the other two conditions (non-linear vs. linear: Q (3,51) = 8.2, $p < 0.01$; non-linear vs. hierarchical: Q (3,51) = 5.2, $p < 0.01$; linear vs. hierarchical ($Q(3,51)$ $p < 1$).

Navigation

Accuracy

The number of questions each subject answered correctly was recorded. The mean number of questions correctly answered are presented in the top row of Table 4.8.

Table 4.8
Mean number of questions correctly answered for experiment 2

	Linear	Hierarchy	Non-Linear
Mean number of questions correctly answered	9.6	9.1	7.2

A one-way ANOVA revealed a significant effect of subject group (F (2,51) = 11.7, $p <$ 0.001). Tukey HSD tests indicated that the non-linear subjects answered fewer questions correctly than the other two subject groups (non-linear vs. linear: Q (3,51) = 6.5, $p <$ 0.01; non-linear vs. hierarchical: Q (3,51) = 5.0, $p < 0.01$; linear vs. hierarchical: Q(3,51) = $p < 1$).

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 are presented in the top row of Table 4.9.

A one-way ANOVA revealed a significant effect of subject group (F (2,51) = 53.5, $p < 0.001$). Tukey HSD tests indicated significant differences between all three subject groups (linear vs. hierarchical: Q (3,51) = 7.0, $p < 0.01$; linear vs. non-linear:Q (3,51) = 14.6, p , 0.01; hierarchy vs. non-linear conditions: Q (3,51) = 7.6, $p < 0.01$). Subjects in the linear condition answered the questions significantly faster than subjects in the hierarchical condition, who in turn responded faster than the subjects in the non-linear condition.

Table 4.9

Mean time and mean number of additional cards opened for experiment 2

	Linear	Hierarchy	Non-linear
Mean Time (in seconds)	80.0	95.8	113.0
Mean number of additional cards	3.9	6.9	10.8

Number of additional cards opened

The number of additional cards opened by each subject to locate the answers to the ten questions was calculated. The mean number of additional cards opened for each of the three conditions is presented in the bottom row of Table 4.9.

A one-way ANOVA revealed a significant effect of subject group (F (2,51) = 42.13, $p < 0.001$). Tukey HSD tests indicated significant differences between all three subject groups: (linear vs. non-linear:Q (3,51) = 12.9, $p < 0.01$; hierarchical vs. non-linear:Q (3,51) = 7.4, $p < 0.01$; linear vs. hierarchical: Q (3,51) = 5.6, $p < 0.01$). Subjects in the linear condition opened significantly fewer additional cards than subjects in the hierarchical condition, who in turn opened fewer additional cards than the subjects in the non-linear condition.

Card Location Task: Time taken

The mean times taken to locate the 5 target cards using the hypertext document was calculated for each subject. The mean time per condition are presented in the top row of Table 4.10.

A one-way ANOVA revealed a significant effect of subject group (F (2,51) = 43.6, $p < 0.001$). Tukey HSD tests indicated significant differences between all three subject groups: (linear vs. hierarchical: Q (3,51) = 5.4, $p < 0.01$; linear vs. non-linear:Q (3,51) = 13.1, $p < 0.01$; hierarchical vs. non-linear:Q (3,51) = 7.7, $p < 0.01$). Subjects in the linear condition located the five target cards significantly faster than the subjects in the hierarchical condition who in turn located the five target cards significantly faster than subjects in the non-linear condition.

Table 4.10

Mean time and mean number of additional cards opened for the card location task for experiment 2

	Linear	Hierarchy	Non-linear
Mean Time (in seconds)	70.0	76.3	85.3
Mean number of additional cards	2.3	5.5	8.5

Card Location Task: Number of additional cards opened

The number of additional cards opened by each subject to locate the 5 target cards was calculated. The mean number of additional cards opened for each of the three conditions is presented in the bottom row of Table 4.10.

A one-way ANOVA revealed a significant effect of subject group. (F (2,51) = 76.4, $p < 0.001$). Tukey HSD tests indicated significant differences between all three subject groups: (linear vs. hierarchical:Q (3,51) = 8.9, $p < 0.01$; linear vs. non-linear:Q (3,51) = 17.5, $p < 0.01$; hierarchical vs. non-linear:Q (3,51) = 8.6, $p < 0.01$) . Subjects in the linear condition opened significantly fewer additional cards than those in the hierarchical condition, who in turn opened significantly fewer cards than those in the non-linear condition.

Questionnaire Data

The top row of Table 4.11 presents the total scores per condition for the disorientation scale, and the bottom row for the perceptions of learning scale. The questionnaire data was 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, (H = 42.8, df = 2, p< 0.001). Analysis for the perceptions of learning scale also revealed a significant difference, (H = 38.3, df = 2, p< 0.001).

Table 4.11
Mean scores for the disorientation and perceptions of learning scales for experiment 2

	Linear	Hierarchy	Non-linear
Disorientation Scale	17.7	33.1	44.9
Learning Scale	18.6	27.6	39.9

Further analysis of the disorientation scale using Mann-Whitney tests revealed significant differences between the scores of all three groups. (linear vs. non-linear: U = -5.1, $p < 0.001$; linear vs. hierarchical: U = -4.9, $p < 0.001$; hierarchical vs. non-linear: U = -4.4, $p < 0.001$). 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.

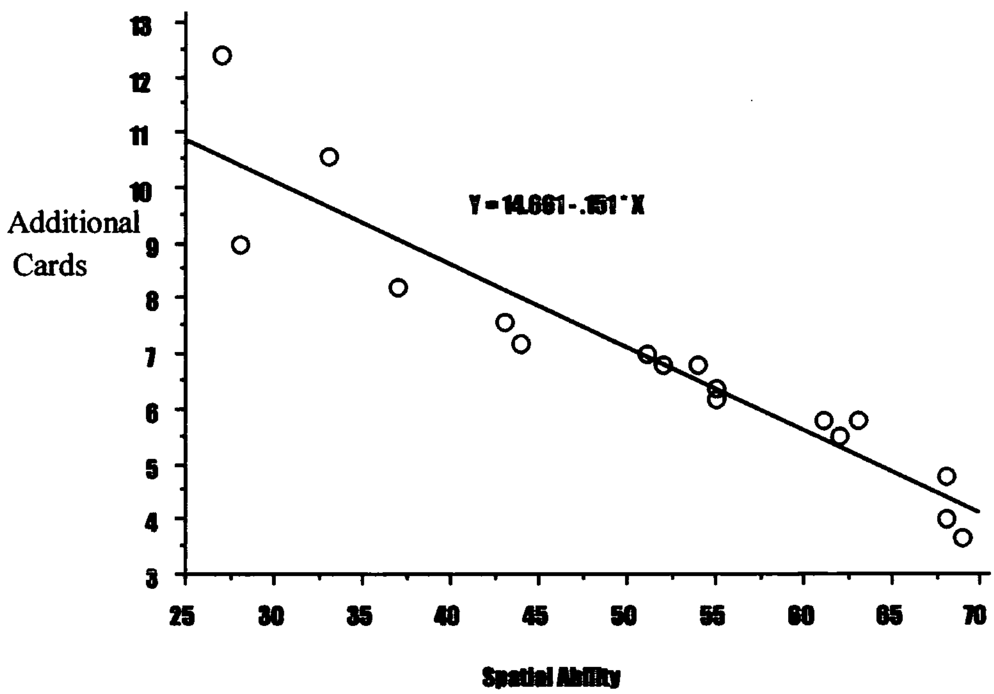
Further analysis of the perceptions of learning scale using Mann-Whitney tests revealed significant differences between the scores of all three groups. (linear vs. non-linear: U = -5.01, $p<0.001$; linear vs. hierarchical: U = -4.7, $p<0.001$; hierarchical vs. non-linear: U = -3.7, $p<0.001$). The subjects' perceptions of learning in the linear condition were more positive than those subjects in the hierarchical condition, who in turn, were more positive than subjects in the non-linear condition.

Spatial Skills

The subjects' performance on the spatial skills test administered during the distraction period was correlated with subjects' performance on the navigational measures. The results showed that for subjects in the linear text condition there was no correlation between navigation performance and spatial ability (r = -.37, $p < 0.13$). However, for subjects in the hierarchical and non-linear conditions the correlation between spatial ability and navigation performance was found be significant (hierarchy: r = -.94, $p < 0.01$; non-linear: r = -.95, $p < 0.01$). Thus, as the subjects' scores on the spatial skills inventory increased the number of additional cards opened during navigation decreased. The results for the hierarchical and non-linear conditions were also subjected to a regression analysis. The values for each variable in the hierarchical condition are plotted in Figure 4.1 and the regression estimates and analysis of variance are summarised in Table 4.12.

Figure 4.1

Scattergram depicting the regression of spatial ability against the number of additional cards opened in the hierarchical condition for experiment 2



The regression model for the hierarchical condition had an R^2 value of 0.88, a Standard Error of 0.76, and the residuals were normally distributed. For the non-linear condition the regression model had an R^2 value of 0.92, a Standard Error of 0.68, and the residuals were normally distributed. The values for each variable in the non-linear condition are plotted in Figure 4.2 and the regression estimates and analysis of variance are summarised in Table 4.13.

Table 4.12

Summary of regression estimates and analysis of variance for regression of spatial ability and mean number of additional cards opened by subjects in the hierarchical condition for experiment 2

Variable	Estimate	SE	*t*	Sig *p*<
(Constant)	14.661369	0.729604	20.095	0.0001
Spatial score	-0.151032	0.013762	-10.975	0.0001

Analysis of Variance

Source	DF	SS	MS	F	Sig p<
Regression	1	69.80701	69.80701	120.44789	0.0000
Residual	16	9.27299	0.57956		

Figure 4.2

Scattergram depicting the regression of spatial ability against the number of additional cards opened in the non-linear condition for experiment 2

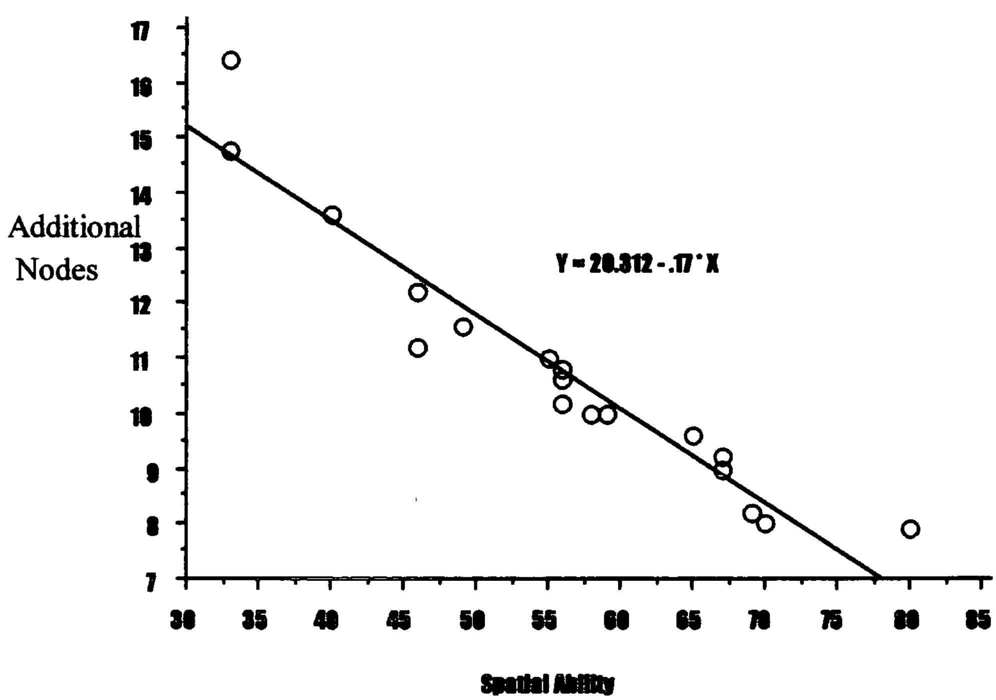


Table 4.13

Summary of regression estimates and analysis of variance for regression of spatial ability and mean number of additional cards opened by subjects in the non-linear condition for experiment 2

Variable	Estimate	SE	*t*	Sig *p*<
(Constant)	20.312287	0.7295545	27.842	0.0001
Spatial score	-0.170469	0.012748	-13.372	0.0001

Analysis of Variance

Source	DF	SS	MS	F	Sig p<
Regression	1	82.54384	82.54384	178.82106	0.0000
Residual	16	7.38560	0.46160		

DISCUSSION

On all measures, performance on the linear text was significantly better than performance on the non-linear text, while performance on 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. This pattern of results was reinforced by the results of the questionnaire data. The results therefore confirm the findings of experiment 1 and those of McKnight, Dillon, and Richardson, (1990), who also found impaired performance with hypertext.

One measure on which the present results differed from those of experiment 1, is the number of questions correctly answered. Subjects using the linear and hierarchical documents answered more questions correctly than subjects using the non-linear text. In the previous study although subjects using hierarchical, and non-linear texts appeared to experience navigational problems, they could still use the documents to answer the ten questions correctly. It is likely that these different results are due to the different levels of prior knowledge of the two sets of subjects used. The subjects in the first study were all postgraduate students who were familiar with the concepts being discussed in the text, which undoubtedly will have helped them locate the answers to the questions. The subjects in the current study, however, were all new first year undergraduates, who at the time of the experiment were unfamiliar with the concepts and ideas presented in the text. Consequently, these findings indicate that the problem of disorientation in hypertext is heightened for novice learners.

The analysis of the questionnaire data confirmed the differences in the performance measures. Subjects who had used the linear text reported having experienced fewer navigational problems than subjects who had used the non-linear and, to a lesser extent, the hierarchical document. Moreover, subjects in the linear condition also reported that they felt they had learnt more about the materials, and expressed greater confidence in their performance than subjects who had used the hierarchical document, who in turn gave more positive perceptions of their learning than subjects who had used the non-linear text. Subjects in the non-linear condition and the hierarchical condition also reported that they felt uncomfortable taking responsibility for choosing where to look in the hypertext, 77% of subjects in the hypertext conditions as compared to 27% of subjects in the linear condition agreed with the statement *"I would have preferred the text to be presented in the same way as a book"*, and 86% of subjects in the hypertext conditions as compared to 22% of subjects in the linear condition agreed with the statement *"I would have preferred the computer or the experimenter to guide me through the document"* . These findings contrast with those of Kinzie and Sullivan, (1989), and Ross et al, (1989), who found that high levels of control produced more positive attitudes to the learning situation in a computer aided learning environment. However, this environment was rather different from hypertext, and the text used in these studies was much shorter than that used in the present study, and although subjects were given control over the sequencing of the computer aided lessons, they were not allowed as much freedom as in hypertext. Thus, in a hypertext environment with long texts, the high levels of control required produced negative attitudes to learning.

The number of additional cards opened by subjects during the questions answer task was also correlated with the subjects' score on the spatial sub-scale of the NFER Nelson General Ability Scale. The results showed that for subjects in the linear condition there was no relationship between spatial ability and navigation performance. However, for the hierarchical and non-linear conditions the results show that spatial ability is correlated with navigation performance. That is, subjects with high spatial scores open fewer additional cards than subjects with low spatial scores. Further analysis of the results for the non-linear and hierarchical conditions using regression analysis revealed that spatial ability seems to be a reliable predictor of navigation performance in hypertext. These results support those of Campagnoni and Ehrlich (1989) who also found that subjects with good spatial skills demonstrated more efficient navigation performance, and the results of experiment 1.

EXPERIMENT 3

METHOD

Subjects

Thirty first year undergraduate volunteers from Durham University served as subjects and were paid for their participation. Their ages ranged from 18 to 25 years. Subjects were unfamiliar with the topic of the experimental text. All subjects had some previous experience of using computers. Each subject was tested individually.

Materials

The same materials were used as in experiment 2. A full list of the navigation questions used in this experiment can be found in Appendix D.

Design

The design was the same as that used in experiments 1 and 2 except that an additional within subjects variable of test phase was added (test phase one before a distraction task, test phase two after a distraction task). The subjects then used the document to find the answers to ten questions. After a distraction period, they returned to the document to locate the answers to a further ten questions. Assignment of question set to test phase 1 or 2 was counterbalanced across the experiment.

Procedure

The procedure was the same as experiments 1 and 2 except that after the distraction task, subjects were required to use the hypertext document to answer a further 10 questions. The presentation order for the ten questions was randomised for each subject.

RESULTS

Browsing

Number of different cards opened

The mean number of different nodes opened during browsing for each condition are presented in the top row of Table 4.14.

Table 4.14
Mean number of different cards opened and mean number of repeated cards opened during browsing for experiment 3

	Linear	Hierarchy	Non-linear
Mean number of different cards opened during reading	43.0	29.4	19.3
Mean number of cards repeated	0.0	2.4	5.0

A one-way ANOVA revealed a significant effect of subject group. (F (2,27) = 62.4 p < 0.001). Tukey HSD tests indicated significant differences between all three subject groups. (linear vs. non-linear: Q (3,27) = 15.7, p <0.01; linear vs. hierarchical: Q (3,27) = 9.0, p < 0.01; hierarchy vs. non-linear: Q (3,27) = 6.7, p < 0.01). Subjects in the linear condition opened more cards during browsing than subjects in the hierarchical condition, who in turn, opened more cards than subjects in the non-linear condition.

Number of repeated cards opened

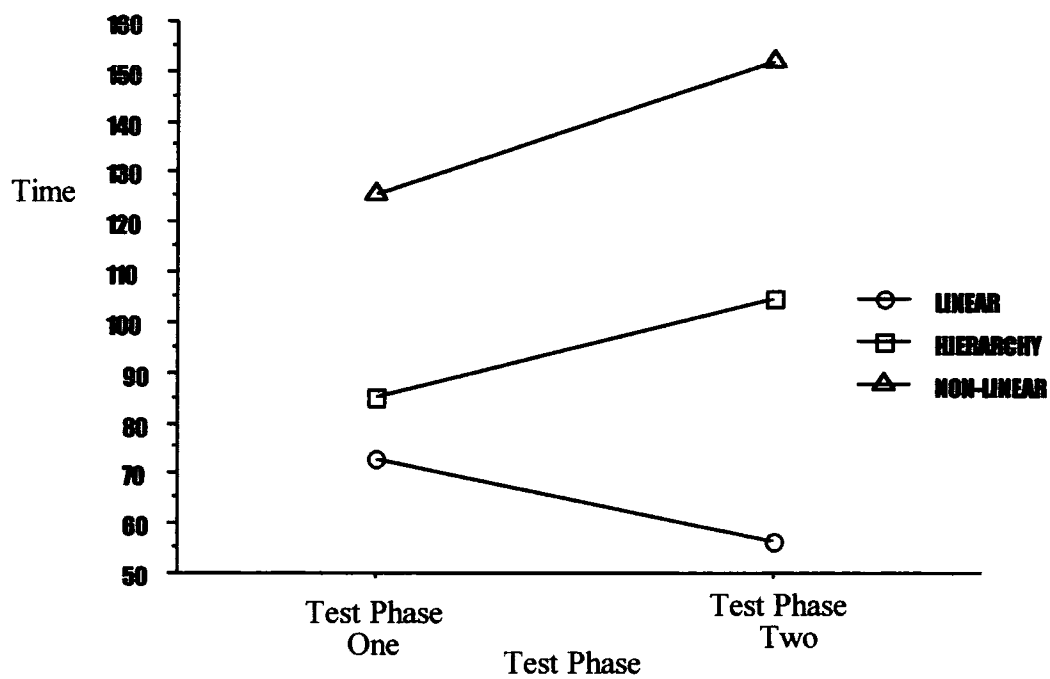
The number of cards that were opened repeatedly by each subject (excluding backtracks) were recorded. The mean number of repeated cards opened during reading is presented in the bottom row of Table 4.12. A one-way ANOVA revealed a significant effect of subject group. (F (2,27) = 29.9 p < 0.001). Tukey HSD tests indicated significant differences between all three subject groups. (linear vs. non-linear: Q (3,27) = 10.9, p <0.01; linear vs. hierarchical: Q (3,27) = 5.3, $p < 0.01$; hierarchy vs. non-linear: Q (3,27) = 5.7, $p < 0.01$). Subjects in the non-linear condition opened more of the same cards repeatedly (excluding backtracks) during browsing than subjects in the hierarchical condition, who in turn, opened more repeated cards than subjects in the non-linear condition.

NAVIGATION

Time taken

The mean time taken to answer the ten questions for test phases one and two, were calculated for each subject. Figure 4.3 presents the mean times in each phase for all three subject groups. A between and within subjects ANOVA revealed two significant main effects: hypertext topology, ($F(2,27) = 25.1$, $p < 0.001$), and test phase ($F(2,27) =$ 4.9, $p < 0.05$). Tukey HSD tests indicated significant differences between all three groups, (linear vs. non-linear: $Q(3,27) = 9.9$, $p < 0.01$; linear vs. hierarchical: $Q(3,27) =$ 5.9, $p < 0.01$; hierarchical vs. non-linear: $Q(3,27) = 4.1$, $p < 0.05$). Subjects in the linear condition performed significantly faster than subjects in the hierarchical condition, who in turn performed faster than subjects in the non-linear condition. The main effect of Test Phase arose because subjects performed significantly slower in Test Phase 2 (mean = 104.4), than in Test Phase 1 (mean = 94.6). However, there was also an interaction between hypertext topology and test phase ($F(2,27)= 9.2$, $p < 0.001$). This interaction modified the main effect of test phase. The main effect of test phase held for the non-linear and hierarchical conditions but not for the linear condition (non-linear: $Q(3,27)=$ 4.9; hierarchical $Q(3,27)= 3.6$; linear $Q = 3.1$, ns).

Figure 4.3
Mean time (in seconds) to answer questions as a function of text structure and test phase for experiment 3



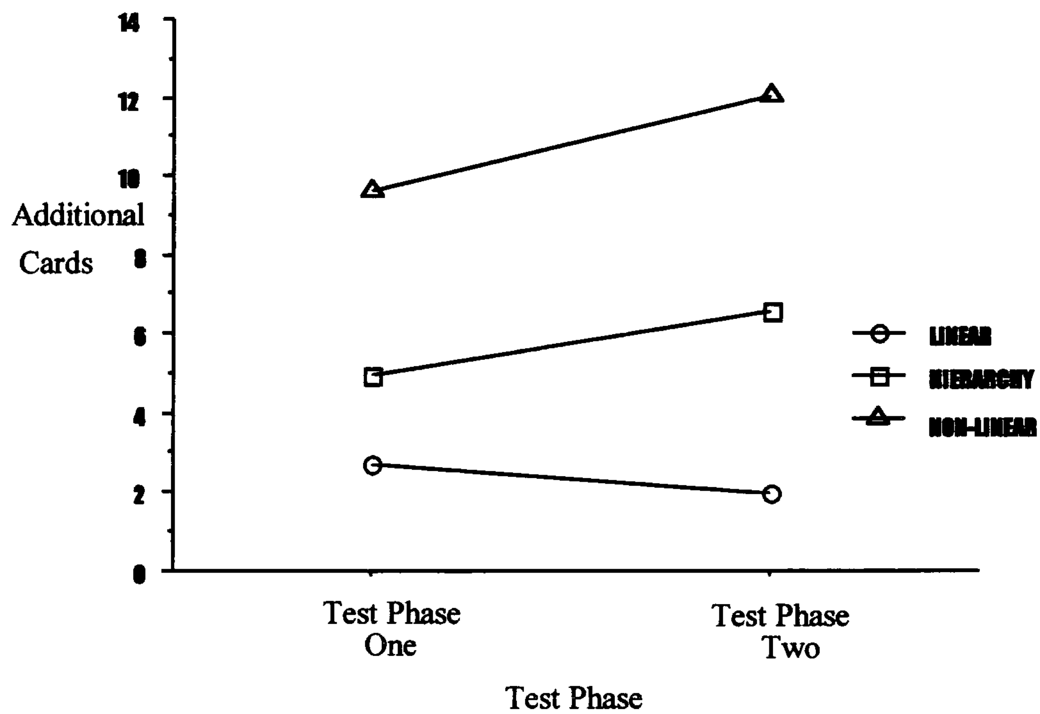
Number of additional cards opened when locating answers to questions

The mean number of cards opened over and above the minimum needed to locate each answer was calculated for each subject for test phases one and two. Figure 4.4 presents the mean number of cards opened for all three subject groups in each test phase. A between and within subjects ANOVA revealed two significant main effects: hypertext topology, ($F(2,27) = 55.7$, $p < 0.001$), and test phase ($F(2,27) = 7.5$, $p < 0.01$). Tukey HSD tests indicated significant differences between all three groups, (linear vs. non-linear: $Q(3,27) = 14.8$, $p < 0.01$; linear vs. hierarchical: $Q(3,27) = 5.9$, $p < 0.01$; hierarchical vs. non-linear: $Q(3,27) = 8.9$, $p < 0.01$). Subjects in the linear condition opened significantly fewer additional cards than subjects in the hierarchical condition, who in turn opened fewer cards than subjects in the non-linear condition.

The main effect of Test Phase arose because subjects opened significantly more additional cards in Test Phase 2 (mean = 6.9), than in Test Phase 1 (mean = 5.7). There was also an interaction between hypertext topology and test phase ($F(2,27)= 5.8$, $p < 0.01$). The main effect of test phase held for the non-linear and hierarchical conditions

Figure 4.4

Mean number of additional cards opened during question answering as a function of text structure and test phase for experiment 3

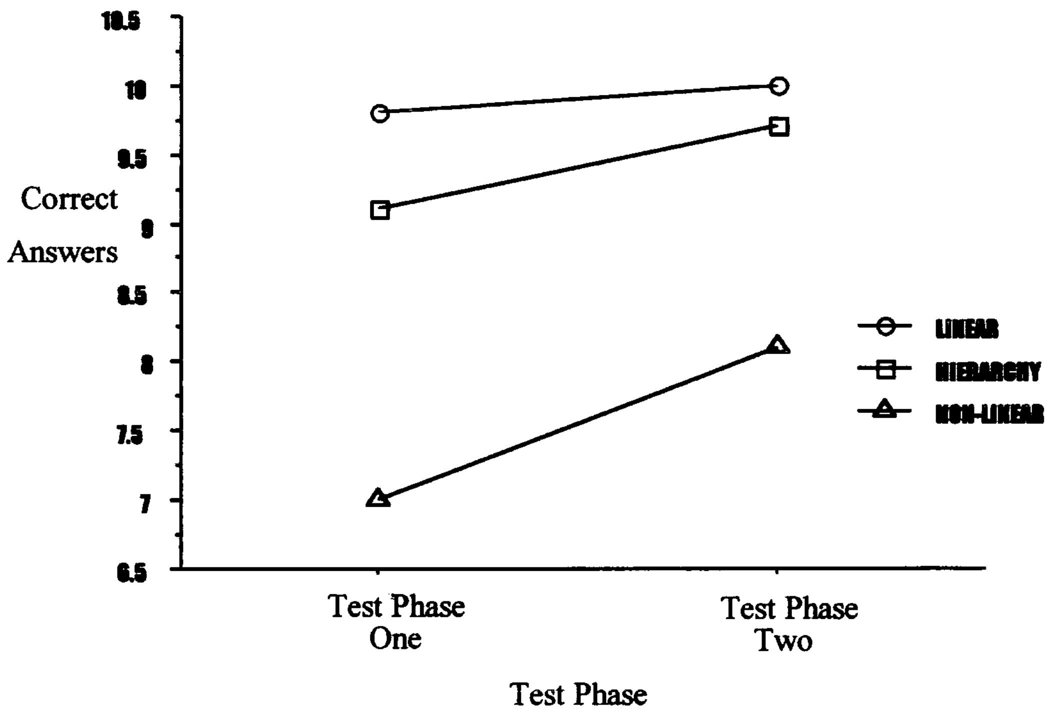


Accuracy of questions answered

The mean number of questions correctly answered in test phases one and two, was calculated for each subject. Figure 4.5 presents the mean number of questions correctly answered for all three subjects groups in each test phase. A between and within subjects ANOVA revealed a significant main effect of hypertext topology ($F(2,27) = 26.7$, $p < 0.001$). Tukey HSD tests indicated that the non-linear subjects answered significantly fewer questions correctly than the other two subject groups, (linear vs. non-linear: $Q(3,27) = 9.8$, $p < 0.01$; hierarchical vs. non-linear: $Q(3,27) = 7.7$, $p < 0.01$). Although subjects in the linear condition, answered more questions correctly than subjects in the hierarchical condition the difference between these two subject groups was not significant ($Q = 2.1$ ns). There were no other significant effects.

Figure 4.5

Mean number of questions correctly answered as a function of text structure and test phase for experiment 3



Spatial Skills

The subjects' performance on the spatial skills test administered during the distraction period was correlated with subjects' performance on the navigational measures. The results showed that for subjects in the linear text condition the correlation between spatial ability and the number of additional cards opened was found not to be significant ($r = -.02$, $p < 0.95$). However, for subjects in the hierarchical and non-linear conditions the correlation between spatial ability and navigation performance was found be significant (hierarchy: $r = -.95$, $p < 0.001$; non-linear: $r = -.97$, $p < 0.001$). Thus, as the subjects' scores on the spatial skills inventory increased the number of additional cards opened during navigation decreased.

The results for the hierarchical and non-linear conditions were also subjected to a regression analysis. The values for each variable in the hierarchical condition are plotted in Figure 4.6 and the regression estimates and analysis of variance are summarised in Table 4.15.

Figure 4.6

Scattergram depicting the regression of spatial ability against the number of additional cards opened in the hierarchical condition for experiment 3

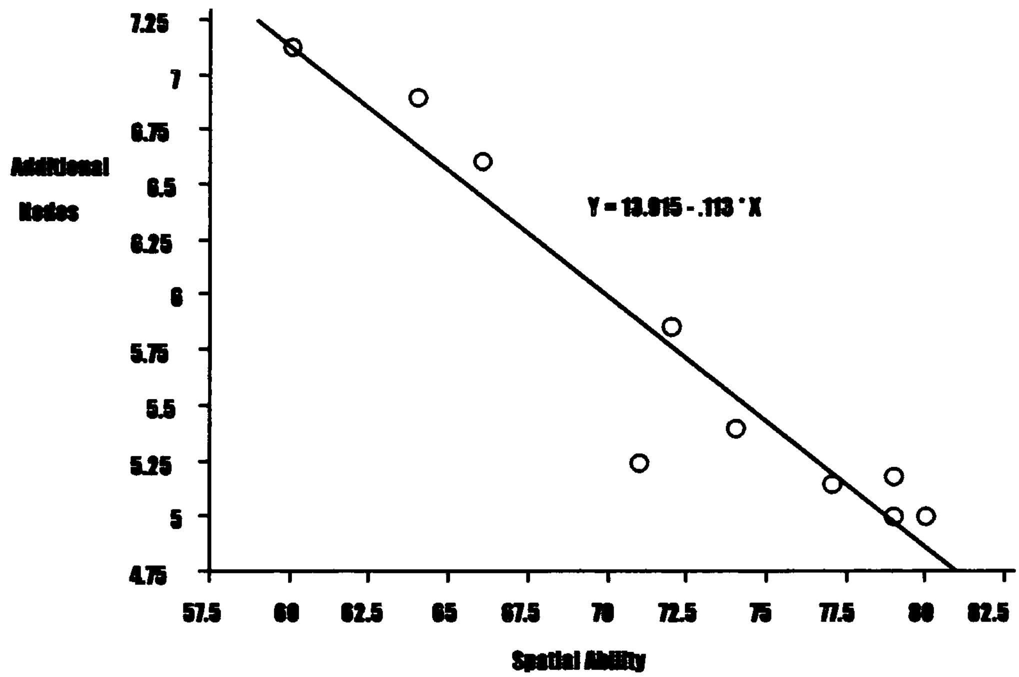


Table 4.15

Summary of regression estimates and analysis of variance for regression of spatial ability and mean number of additional cards opened by subjects in the hierarchy condition for experiment 3

Variable	Estimate	SE	*t*	Sig *p*<
(Constant)	13.905636	0.933943	14.889	0.0000
Spatial score	-0.112994	0.012882	-8.772	

Analysis of Variance

Source	DF	SS	MS	F	Sig p<
Regression	1	5.56154	5.56154	76.94059	0.0000
Residual	8	0.57827	0.07228		

The regression model for the hierarchical condition had an R^2 value of 0.91, a Standard Error of 0.26886, and the residuals were normally distributed. For the non-linear condition the regression model had an R^2 value of 0.94, a Standard Error of 0.78264, and the residuals were normally distributed. The values for each variable in the non-linear condition are plotted in Figure 4.7 and the regression estimates and analysis of variance are summarised in Table 4.16.

Figure 4.7

Scattergram depicting the regression of spatial ability against the number of additional cards opened in the non-linear condition for experiment 3

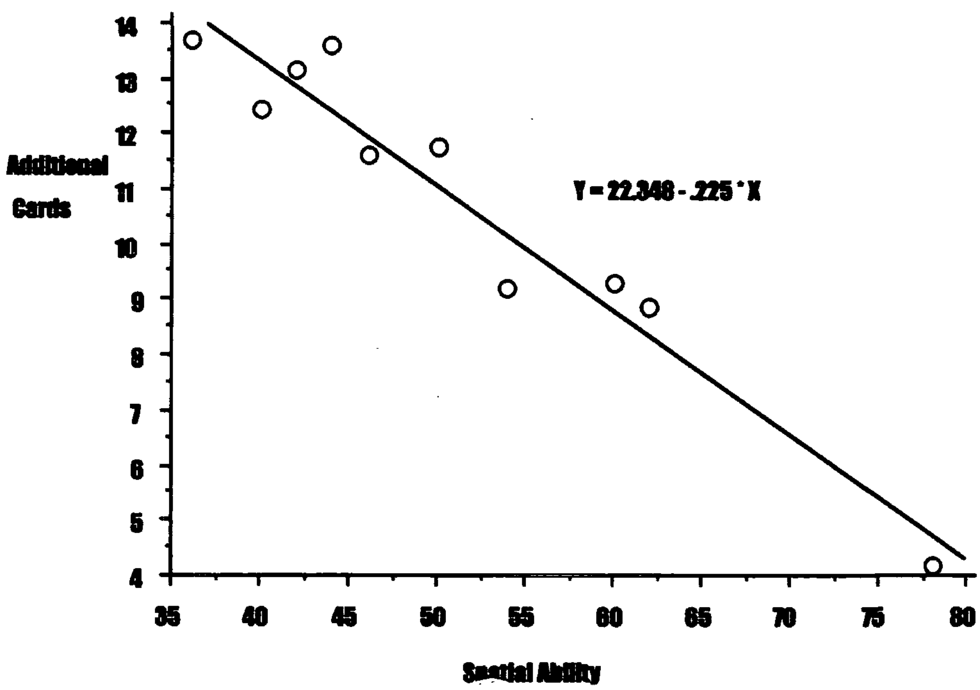


Table 4.16

Summary of regression estimates and analysis of variance for regression of spatial ability and mean number of additional cards opened by subjects in the non-linear condition for experiment 3

Variable	Estimate	SE	*t*	Sig *p*<
(Constant)	22.341324	1.084014	20.610	0.0000
Spatial score	-0.225368	0.020613	-10.933	0.0000

Analysis of Variance

Source	DF	SS	MS	F	Sig p<
Regression	1	73.21969	73.21969	119.53705	0.0000
Residual	8	4.90022	0.61253		

DISCUSSION

The results show that performance was best with the linear text, next best with the hierarchical hypertext, and poorest with the non-linear hypertext. The ease of finding the answers to the questions was better immediately after browsing (test phase one) than after a delay (test phase 2), but only with the hierarchical and non-linear texts. With the linear text, the subjects' performance remained the same after a delay. Taken together, these results suggest that 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. These findings support those of McKnight *et al* (1990), and experiments 1 and 2 which also found that subjects performed better using a linear document than hypertext.

In terms of reading, our results demonstrate that when subjects are left to decide what to read, and when to stop reading, they can't judge when they have read enough, and have problems selecting which parts of the text to focus on. Subjects in the non-linear condition opened very few cards during reading, often neglecting to view entire sections of the document. These findings lend support to those of experiments 1 and 2. These problems may arise either because the subjects couldn't find the information they required or because they continually made poor selections concerning which route to follow through the document. The latter explanation is supported by the fact that subjects in the non-linear condition opened the same few cards repeatedly, a browsing behaviour previously observed by Simpson and McKnight, (1991), which suggests the subjects were disorientated.

The results of the question answering task showed that subjects in the linear condition found the answers to the questions significantly faster and opened fewer additional cards than subjects in the hierarchical and non-linear conditions. Similarly, subjects in the hierarchical condition performed significantly faster and opened fewer additional cards than their non-linear counterparts. The interaction between text structure and test phase suggests that the subjects gain a better grasp of the text structure when reading the linear text compared to the other two. This shows itself in two ways. First, performance at both test phases is better with the linear text; second, performance on the linear text remains the same after a delay while performance on the other two texts declines. This latter result suggests that grasp of text structure is weak and unstable after reading the non-linear and hierarchical texts, and so is vulnerable to distraction. The number of correct answers to the questions only showed that performance with the non-linear text was poorer than with the other two texts. This difference from the findings on the other two question answering tasks is probably due to a ceiling effect. We deliberately used easy questions because we were primarily concerned with discovering how easily the subjects could find the answers, not with whether they could answer the questions having found the information.

The number of additional cards opened by subjects during the questions answer task was also correlated with the subjects' score on the spatial sub-scale of the General Ability Scale. The results showed that for subjects in the linear condition there was no relationship between spatial ability and navigation performance. However, for the hierarchical and non-linear conditions the results show that spatial ability is correlated with navigation performance. Subjects with high spatial scores open fewer additional cars than subjects with low spatial scores. Further analysis of the results for the non-linear and hierarchical conditions using regression analysis revealed that spatial ability seems to be a reliable predictor of navigation performance in hypertext. These results support those of Campagnoni and Ehrlich (1989) who also found that subjects with good spatial skills demonstrated more efficient navigation performance, and the results of experiments 1 and 2.

GENERAL DISCUSSION

Collectively, the results of experiments 1,2 and 3 suggest 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. The difference in performance between the linear and hypertext conditions may be accounted for by two factors, learner control and learner expertise. Taking the factor of control first, the results for the reading stage demonstrate that when subjects are left to decide what to read, and when to stop reading, they can't judge when they have read enough, and have problems selecting which parts of the text to focus on. These findings lend support to those of Kieras (1985); Shin, et al (1994). Past research on normal texts has shown that subjects are not very good at assessing the relative importance of the text they are reading, and are even worse at anticipating whether important information remains to be viewed in the parts of the text they have not read (Charney, 1994). These problems appear to be exacerbated in the case of hypertext either because the subjects couldn't find the information they required, or because they didn't realise the extent of the knowledge base. Moreover, readers expect texts to conform to certain criteria or types, and to be structured and presented in a particular format. Most educational texts are sequential, in that they are presented in a fixed linear order. The linear document will have conformed to the subjects' expectations of how the text would be structured, therefore they will have been able to use the document more easily. The linear document also offered the least amount of user control in terms of the number of links or directions in which the subjects could travel. There was only one route through the document, so there was very little opportunity for the subjects to get lost. They knew that the information they required was either going to be further forward or further back in the document.

The difference in performance between the hierarchical and non-linear documents also appears to be due to the different level of user control offered by the two hypertext organisations. Although the hierarchical document does not constrain the user to a single path through the document, its organisational structure does confine the users' movements, and necessarily their freedom to browse. However, the non-linear structure places few constraints on the user's movements, they have unlimited freedom to explore a richly connected non-linear 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.

Turning to the factor of learner expertise, the results of the question answer task in experiment 2 demonstrate that novice users have greater difficulty in locating and extracting information in hypertext than advanced users. These results are consistent with McGrath, (1992), and Shin, et al, 1994, in that novice learners are impaired in their reading and understanding of hypertext documents, particularly non-linear documents. McGrath and Shin et al also found that skilled learners were unaffected by hypertext, whereas experiment 1 found that they were disrupted by hypertext. This difference in results is probably due to the length of the text used in the different studies. The text used in experiment 1 was considerably longer than those used by McGrath and by Shin et al. The results of experiment 1 suggest that hypertext can be a problem for skilled learners as well as for novices, although unlike novices, skilled learners may not suffer in terms of accuracy.

Turning to the relationship between navigation performance and individual differences in spatial ability. The results of all three studies showed that for the linear condition there was no relationship between spatial ability and navigation performance. However, for the hierarchical and non-linear conditions the results show that spatial ability is correlated with navigation performance. Subjects with high spatial scores open fewer additional cards than subjects with low spatial scores. Further analysis of the results for the non-linear and hierarchical conditions using regression analysis revealed that spatial ability seems to be a reliable predictor of navigation performance in hypertext. These findings confirm the suggestion that hypertext occupies space. In order to navigate efficiently through hypertext, users must be able to visualise the structural properties of the document. This suggests that one way to help disorientated users is to provide spatially based navigational aids. The usefulness of such aids is further examined in chapter 6.

The results of this study appear to have a number of implications for the use of hypertext-based learning systems. It would appear that our results suggest that a linear text would be more suitable for learning than hypertext, because subjects appear to be able to use this text type more efficiently, in terms of speed and accuracy. However, this conclusion is based on the assumption that efficient navigation and hence efficient learning is preferable to slower navigation and learning, an assumption that may be incorrect. As discussed in chapter 2, 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 later 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 later to complete a problem solving task that required a deeper understanding of the text, the subjects who had used the different-organisation outline performed best. Thus, while recall of initial learning was easier in the same-organisation group, transfer of learning to a new task was superior in the different-organisation group. Mayes, Kibby, and Anderson, (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 superior learning observed with linear texts carries over to long term learning and transfer, or whether the disorientation experienced with hypertext is a critical variable for successful learning.

The results also suggest that learners themselves express a lack of confidence in their ability to use hypertext, and are uncomfortable with the amount of control hypertext gives them, and generally prefer linear texts to hypertext. On the face of it, there appears to be a strong intuitive appeal in allowing students to choose the methods of instruction they receive. However, research has shown that performance under a preferred mode may lead to lower achievement than participation in a less preferred mode (Carrier, 1984; Tobias, 1972). Snow and Peterson (1980) explain this phenomena by arguing that students often prefer methods of instruction that they think will require less work, concentration, and time. However, if the students do not need to work as hard under preferred modes, they may in fact learn less. The fact that subjects in this study preferred the linear text, presumably because they found it easier and faster to use, does not guarantee that, in the long term, they will learn more from this type of text than from a hypertext document, where they may have to invest more time and effort in the learning process.

However, one major problem highlighted by this study, is that when left to browse hypertext systems, subjects tend to stop reading far too soon, and often neglect to read important information. This aspect of performance with hypertext needs to be carefully addressed before we can assess the full learning potential of hypertext. The observation emphasises that the mere availability of information does not guarantee learning. If hypertext is going to be of any educational value, we need to identify strategies to guide learners' explorations, so that they do not ignore whole sections of the text, and strategies to help them develop the necessary skills for managing their own learning.

SUMMARY

In summary, we have found that disorientation is a problem for hypertext users, especially those unfamiliar with the knowledge domain, and that hypertext topology affects navigation performance. In addition, non-linear texts are a greater problem for users than hierarchical texts, because of the greater amount of user control they provide. It appears therefore, that although non-linear hypertexts 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, this does not necessarily mean that hypertext is inappropriate for information retrieval or learning. Navigation may be improved by modifying the number of links and structure of the text, this is examined in chapter 5. Navigation may also be assisted with the use of navigational aids such as spatial maps, which is examined in chapter 6.

5

Text structure and prior knowledge

INTRODUCTION

The results of experiments 1, 2 and 3 show that disorientation is a problem for hypertext users, especially when the text is of a non-linear structure with a large number of cross-referential links. Therefore, it seems that the increased level of user control offered by these structures in terms of the number of routes the user may follow through the text can have a number of negative consequences. Indeed, the advantages of non-linear texts may be severely limited if users are unable to find their way around unfamiliar and complex information structures without experiencing disorientation. Some researchers feel that such non-linear texts are of limited value, especially to beginners in the subject matter of the text. For example, Brown (1989) argued that complex non-linear hypertext is inappropriate for novice users and suggested that a simple hierarchical structure should be employed with only a few cross-reference links that cut across the hierarchy. Clearly there is a need to identify structures that reduce the possibility of getting lost, but that still embrace the real essence of hypertext, which is to allow users some control over how they access the information.

A major aim of this study was to examine the extent to which different hypertext topologies reduce disorientation relative to a control pure hypertext condition. It is anticipated that the pure hypertext will produce the most disorientation in both browsing and navigation. It is also anticipated that a mixed text, which contains both hierarchical and cross referential links, will produce less disorientation than a purely hierarchical text. The same performance measures were taken as in experiments 1 - 3. As in experiment 3 the subjects' performance is also compared before and after a distraction period in order to assess whether the subjects have enough knowledge of the system structure to re-gain their bearings after a filled delay.

Disorientation may also be modified by the degree of prior knowledge a user has of the subject matter of the hypertext. Previous research has not considered how hypertext structure might interact with the prior knowledge of the user. Hammond

(1989) suggests that disorientation is heightened in the case of novices who are unfamiliar with the subject matter of the text. It seems likely, for example, that compared to novices, more knowledgeable users have fewer navigation problems in hypertext because their greater grasp of the conceptual structure of the subject matter enables them to impose structure on the hypertext. Therefore, it is necessary to examine which text structures may help novices overcome the lack of such conceptual support. This experiment, the effects of knowledge level on disorientation using knowledgeable and non-knowledgeable subjects, in the same experiment, with the texts offering different levels of user control in terms of the number of links available for users to follow, and in the number of directions in which they may travel.

The relationship between individual differences in spatial skills and navigation performance in terms of speed and the directness of the subject's chosen route through the text were also measured to see if the correlation between navigation performance and spatial skill holds for knowledgeable subjects as well as non-knowledgeable subjects.

EXPERIMENT 4

METHOD

Subjects

Thirty paid volunteers from Durham University served as subjects. Half were knowledgeable (postgraduates in psychology) and half were non-knowledgeable (first year undergraduates in psychology) about the subject matter of the text. All subjects had previous experience of using computers. Subjects were tested individually.

Materials

The hierarchical (See Figure 5.1 for an example of a hierarchical structure) and non-linear (See Figure 5.2 for an example of a non-linear structure) hypertext used in experiments 2 and 3 (chapter 4) were also used in this study. In addition a third hypertext document was created with a mixed structure. This mixed structure was composed of a simple hierarchical structure, exactly the same as the hierarchical document. However, a number of cross referential links were implemented allowing users to jump across the branches of the hierarchy (See Figure 5.3 for an example of a mixed structure). A backtrack facility was included in each document. The number of links in each text were hierarchical: 44, non-linear: 70, and mixed: 56. In the mixed text, there were 44 hierarchical links, and 14 cross-referential links.

Design

The same experimental design was used as in experiment 3 (chapter 4). However, an additional independent variable of knowledge level, (knowledgeable and non-knowledgeable) was included. . The performance of subjects' was compared before and after a distraction period (test phases one and two).

Procedure

The same experimental procedure was used as in experiment 3. A full list of the questions used in this study can be found in Appendix D.

Figure 5.1

An example of a hierarchical topology

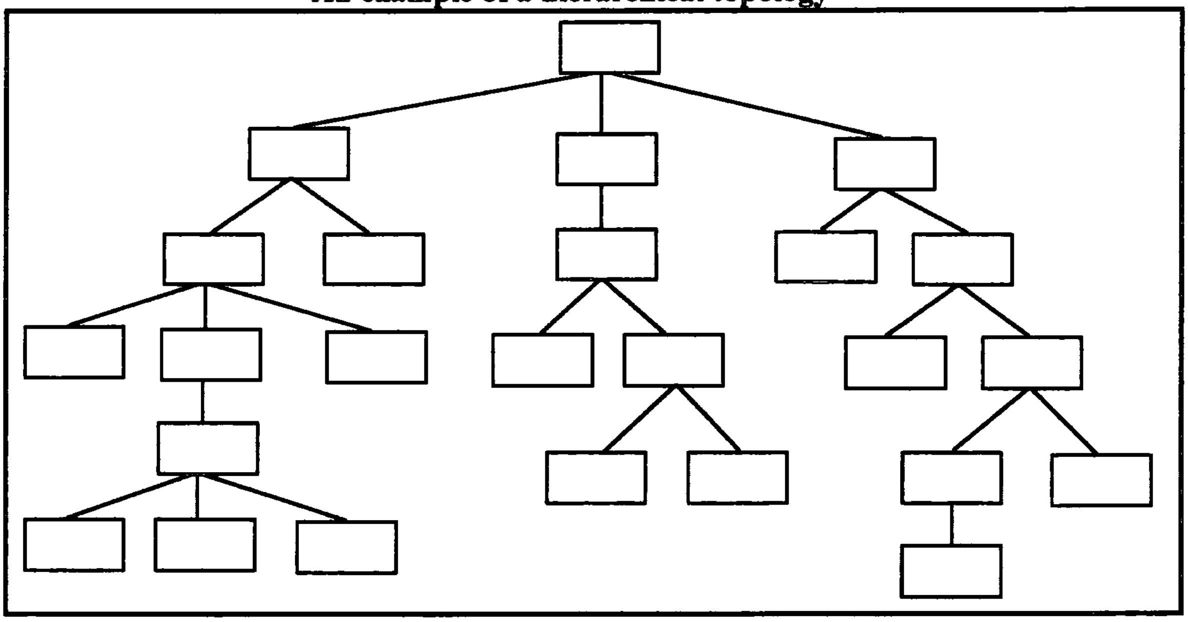


Figure 5.2

An example of a non-linear topology

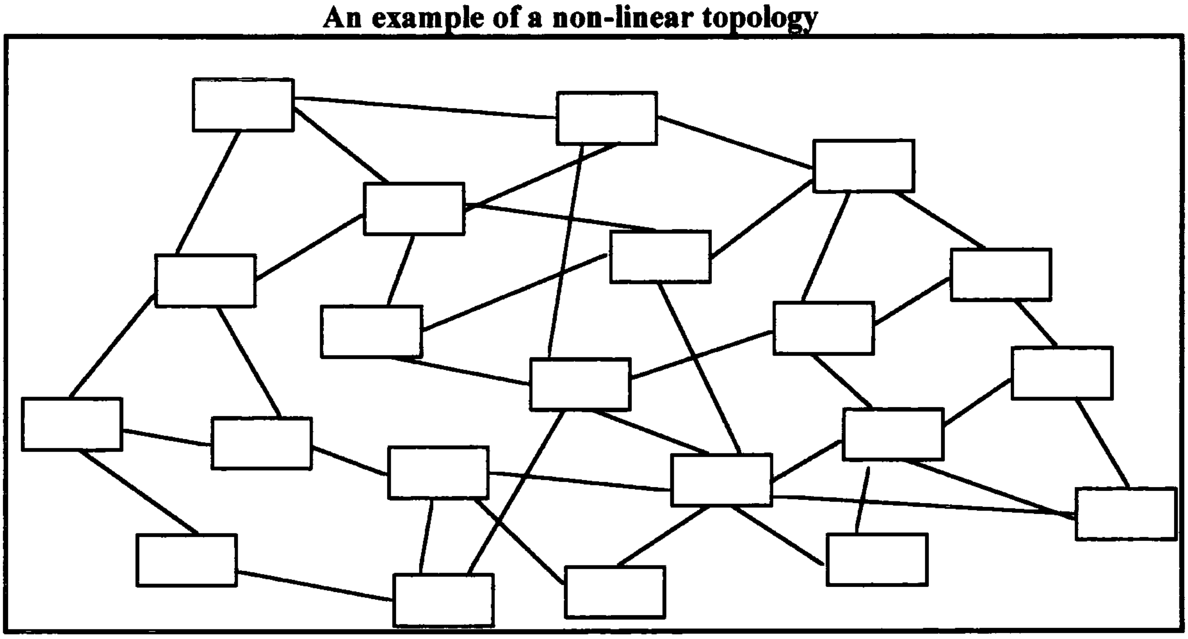
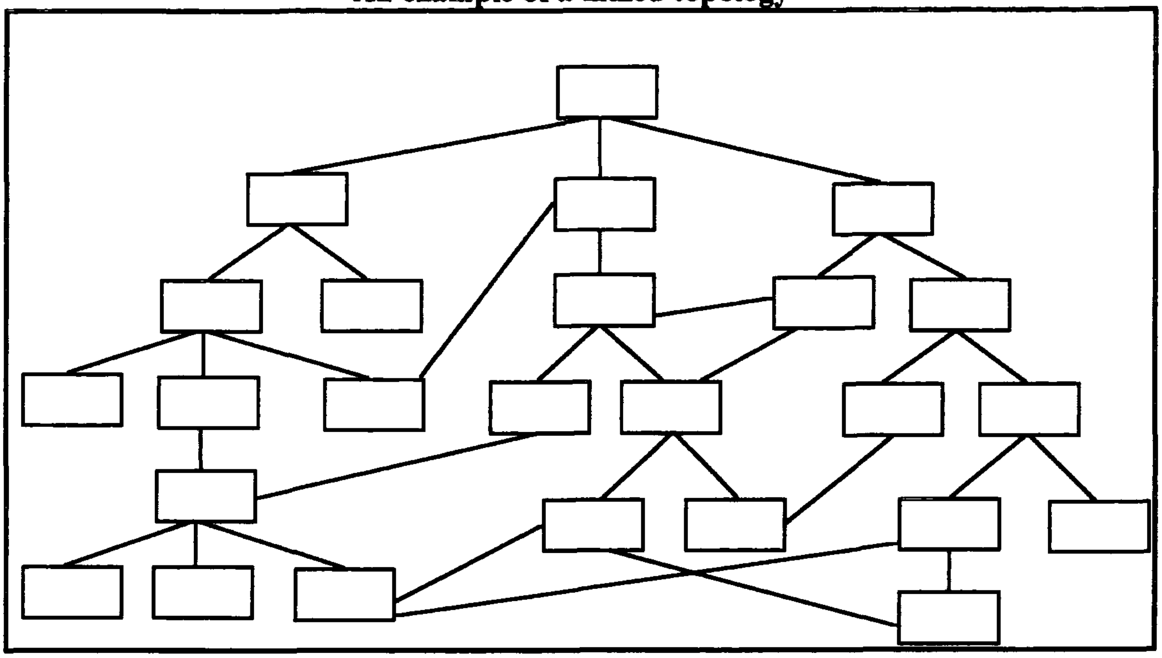


Figure 5.3

An example of a mixed topology



RESULTS

Browsing measures

Number of Cards Opened

The top row of Table 5.1 shows the mean number of cards opened in each condition for each subject group. A between subjects ANOVA revealed main effects of topology ($F(2,24) = 84.6$, $p < 0.01$), and knowledge level ($F(1,24) = 38.4$ $p < 0.01$), and an interaction between the two ($F(2,24) = 8.1$, $p < 0.01$). Tests of simple effects revealed that knowledgeable subjects opened more cards than non-knowledgeable subjects in the hierarchical and non-linear conditions (hierarchical: $F(1,24) = 25.7$, $p < 0.01$; non-linear: $F(1,24) = 28.8$, $p < 0.01$), but not in the mixed condition ($F(1,24)$ $p < 1$).

Number of repeated nodes opened during reading

The bottom row of Table 5.1 shows the mean number of repeated cards opened in each condition for each subject group.

Table 5.1

Mean number of cards opened during reading as a function of knowledge level and hypertext topology for experiment 4

	HIERARCHY		MIXED		NON-LINEAR	
	K	NK	K	NK	K	NK
Cards opened during reading	36.0	25.8	40.8	40.2	27.4	16.6
Repeated cards opened during reading	3.2	5.4	2.2	2.6	4.2	7.0

K = KNOWLEDGEABLE

NK = NON-KNOWLEDGEABLE

A two-way between subjects ANOVA revealed main effects of topology (F (2,24) = 12.2, p < 0.01), and knowledge level (F(1,24) = 11.5, p <0.01). Tukey HSD tests indicated significant differences between the mixed condition and the other two subject groups. (mixed vs. hierarchical: Q (1,24) = 4.1, p < 0.01; mixed vs. non-linear: Q (1,24) = 6.9, p < 0.01) Although subjects in the hierarchical condition opened fewer repeated cards than subjects in the non-linear condition the differences between these two groups were not significant (Q(1,24) = 2.8). The main effect of knowledge level arose because expert subjects opened fewer repeated cards (mean = 3.2) than novice subjects (mean = 5.0). There were no other significant effects.

Navigation measures

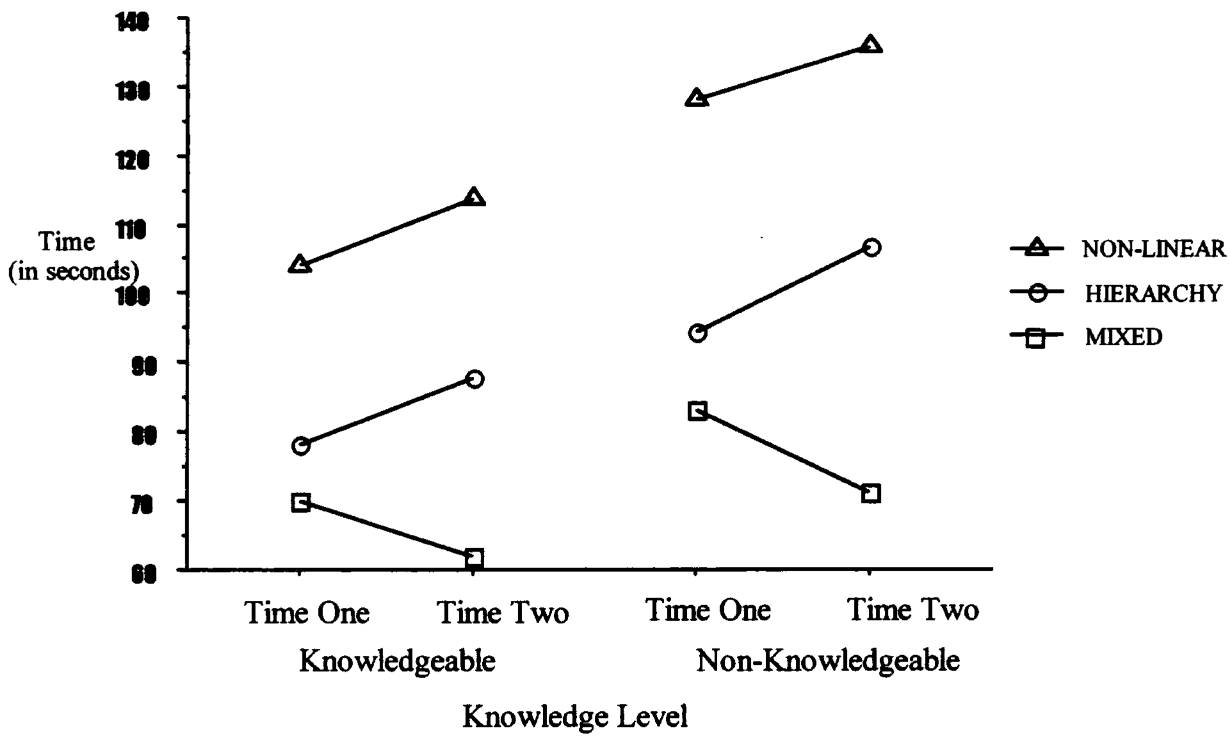
Time Taken

Figure 5.4 shows the mean time to answer the questions in each condition, for each subject group in each test phase. A between and within subjects ANOVA revealed three significant main effects: hypertext topology, (F(2,24) = 24.3, p <0.01), knowledge level (F(1,24) = 8.9, p <0.01), and test phase (F(1,24) = 4.7, p < 0.04). There was also a significant interaction between hypertext topology and test phase (F(2,24) = 19.3, p <0.01). Tests of simple main effects revealed that subjects in the hierarchical and non-linear conditions took significantly longer to answer the questions in test phase two than in test phase one (hierarchy: F(1,24) = 17.8, p <0.01; non-linear F(1,24) = 11.1, p <0.003). However, subjects in the mixed condition answered the questions significantly faster in test phase two than they had in test phase one (mixed: F(1,24) = 14.4, p <0.01).

Topology was statistically significant at both test phases (phase one: F(2,27) = 15.9, p <0.01; phase two F(2,27) = 31.9, p <0.01). Pair-wise comparisons using the Newman Keuls procedure revealed that for test phase one, subjects in the hierarchy and mixed condition performed significantly faster than subjects in the non-linear condition (α <0.01). Although subjects in the mixed condition answered the questions faster than subjects in the hierarchy condition the difference between these two groups was not significant. However, for test phase two, there were significant differences between all three groups (α <0.01).

Figure 5.4

Mean time taken to answer questions as a function of knowledge level and hypertext topology for experiment 4



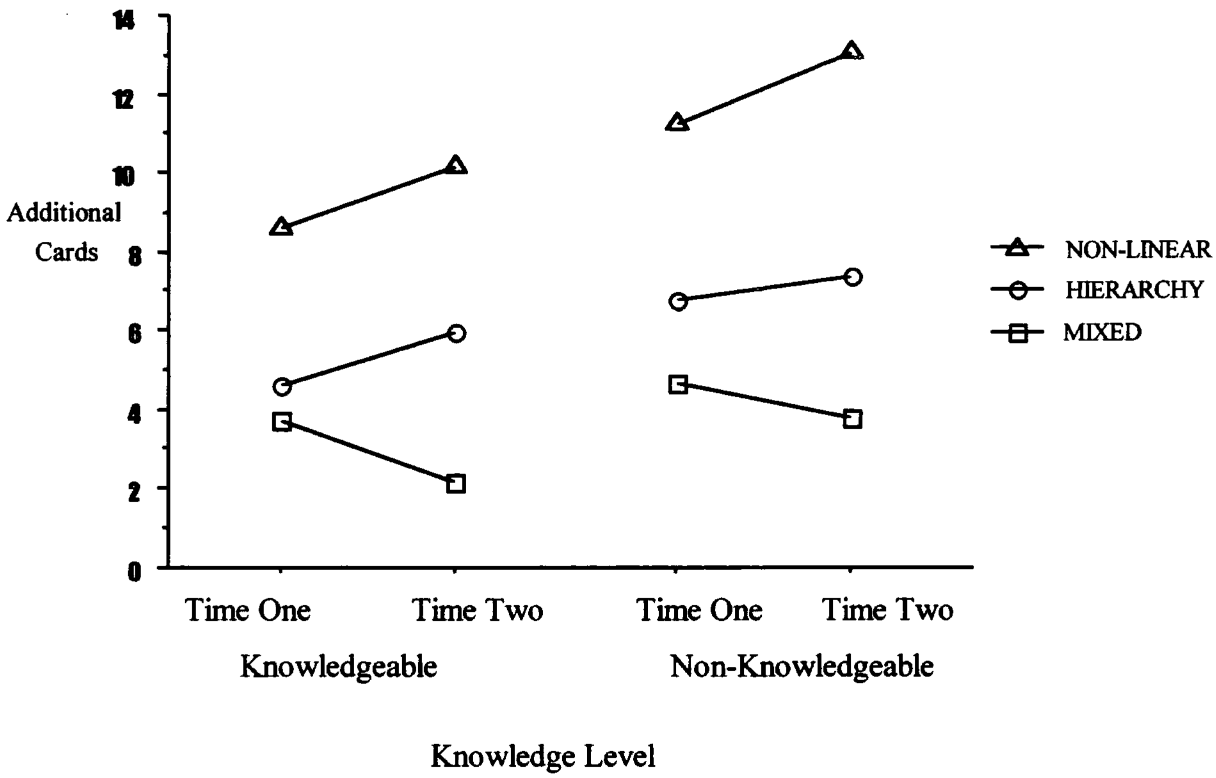
Number of Additional Cards Opened

Figure 5.5 shows the mean number of additional cards opened in each condition, for novice and experts in both test phases.

A between and within subjects ANOVA revealed three significant main effects: hypertext topology, ($F(2,24) = 39.7$, $p < 0.01$), knowledge level ($F(1,24) = 8.8$, $p < 0.01$), and test phase ($F(1,24) = 5.7$, $p < 0.03$). There was also a significant interaction between hypertext topology and test phase ($F(2,24) = 17.6$, $p < 0.01$). Tests of simple main effects revealed that subjects in the hierarchical and non-linear conditions opened significantly more additional cards in test phase two than in test phase one (hierarchy: $F(1,24) = 7.5$, $p < 0.01$; non-linear $F(1,24) = 22.1$, $p < 0.01$). However subjects in the mixed condition opened fewer additional cards in test phase two than in test phase one.(mixed: $F(1,24) = 11.1$, $p < 0.01$)

Figure 5.5

Mean number of additional cards opened when answering the questions as a function of knowledge level and hypertext topology for experiment 4



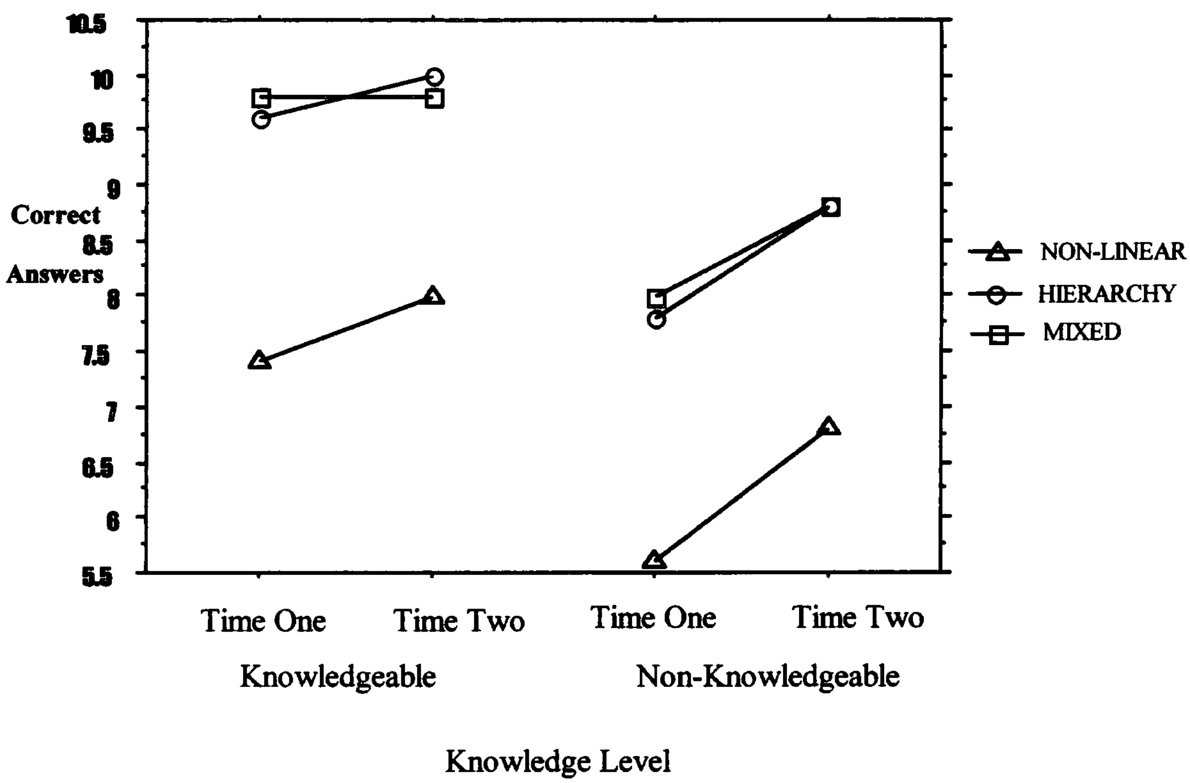
Topology was statistically significant at both test phases (phase one: $F(2,27) = 23.9$, $p < 0.01$; phase two $F(2,27) = 51.4$, $p < 0.01$). Newman Keuls pair-wise comparisons revealed that for test phase one, subjects in the hierarchy and mixed condition opened fewer additional cards than subjects in the non-linear condition ($\alpha < 0.01$). Although subjects in the mixed condition opened fewer additional cards than subjects in the hierarchy condition the difference between these two groups was not significant. However, for test phase two, there were significant differences between all three groups ($\alpha < 0.01$).

Accuracy

The mean number of questions correctly answered in test phases one and two, was calculated for each subject. Figure 5.6 represents the main effects and interactions for all three subject groups across both test phases.

Figure 5.6

Mean number of correct answers as a function of knowledge level and hypertext topology for experiment 4



A between and within subjects ANOVA revealed three significant main effects: hypertext topology, ($F(2,24) = 23.02$, $p < 0.0001$), knowledge level ($F(1,24) = 24.66$, $p < 0.0001$), and test phase ($F(1,24) = 14.55$, $p < 0.0008$). Tukey HSD tests indicated that the non-linear subjects answered significantly fewer questions correctly than the other two subject groups, (mixed vs. non-linear: $Q(3,24) = 8.41$, $p < 0.01$; hierarchical vs. non-linear: $Q(3,24) = 8.21$, $p < 0.01$; mixed vs. hierarchical: $Q(3,24) = 0.19$, ns.). The main effect of knowledge level arose because knowledgeable subjects (mean = 9.10) answered more questions correctly than non-knowledgeable subjects (mean 7.63), while the main effect of test phase arose because subjects answered more questions correctly in test phase two (mean = 8.70), than in test phase one, (mean = 8.03). There were no significant interactions between the three factors.

Spatial Skills

The subjects' performance on the spatial skills test administered during the distraction period was correlated with subjects' performance on the navigational measures. The correlation between the number of additional cards opened for the hierarchical condition was: knowledgeable subjects $r = -0.89$, $p < 0.04$, non-knowledgeable subjects $r = -0.90$, $p < 0.04$; for the mixed condition knowledgeable subjects $r = -0.98$, $p < 0.003$, non-knowledgeable subjects $r = -0.92$, $p < 0.03$; for the non-linear condition, knowledgeable subjects $r = -0.90$, $p < 0.04$, non-knowledgeable subjects $r = -0.90$, $p < 0.04$. As the subjects' scores on the spatial skills inventory increased the number of additional cards opened during navigation decreased. Thus these results indicate that spatial skills are correlated with navigation performance. That is, those subjects with good spatial skills demonstrated better navigation performance than those subjects with poor spatial skills. These correlations held for both non-knowledgeable and knowledgeable subjects.

DISCUSSION

These results show that both the structure of the text and the knowledge level of the subjects affects the ease with which hypertext can be used. In both browsing and navigation the mixed text produced the best performance, the hierarchical the next best and the non-linear the poorest. Knowledgeable subjects also performed better than non-knowledgeable subjects. However, text structure and knowledge level interacted during browsing: The difference between knowledgeable and non-knowledgeable subjects disappeared with the mixed text, where non-knowledgeable subjects opened as many nodes as knowledgeable subjects. Also, text structure and test phase interacted during navigation: while performance at test phase 2 was poorer than at test phase 1 for the hierarchical and non-linear texts, the reverse was the case for the mixed text where performance at test phase 2 was better than at test phase one.

The difference between the non-linear condition and the other two text conditions most likely arises because of the different levels of control offered by the three text structures. The non-linear text places few constraints on users' movements, giving the subjects unlimited freedom to explore the network. However, this freedom has its associated costs. Users seem overwhelmed by the choices offered by non-linear hypertext This places a high cognitive burden on the learners in that they must simultaneously focus on their information retrieval goals, and on orienting themselves within the hypertextual space. Consequently their navigation performance declines and they can be said to be disorientated.

Perhaps more interesting is the difference between the hierarchical and mixed texts. The hierarchical document did not constrain users to a single path through the document, but its organisational structure did confine their movements to some degree and necessarily their freedom to browse. Although the mixed condition shares the same basic structure it also has a number of cross-referential links that allow subjects to jump across the hierarchy to new sections of the document. The navigation results suggest that this text organisation offered the best mixture of freedom and constraint. The cross-referential links allowed the subjects the freedom to jump across the hierarchy to other sections of the document, without having to traverse back up to the top of the hypertext. For example, moving from a leaf node at the bottom of one hierarchical branch to another leaf node in a separate branch may require the user of the hierarchical text to traverse fourteen cards, whereas, the user of the mixed text could make the same journey with only a single click of the mouse button. This may account for the speed at which subjects located the answers to the questions, and the accuracy of their chosen route through the document. Although this structure allowed the users the freedom to jump across into new sections of the document, its basic hierarchical framework served to constrain the users movements, preventing them from getting lost.

Navigation with the mixed text improved after a delay. When reading all three texts, it is likely that subjects spend a considerable amount of time and effort trying to grasp the structure of the text as they read it. The interaction between text structure and test phase during navigation suggests that the subjects gain a better grasp of the text structure when reading the mixed text compared to the other two. The better performance at test phase two than at test phase one suggests that the grasp of text structure is weak and unstable after reading the non-linear and hierarchical texts, while it is stronger and more durable after reading the mixed text, consolidating over time.

The most likely reason for the superior performance of knowledgeable subjects is that they have an understanding of the conceptual organisation of the subject matter that can allay some of the disorientation problems that arise with non-linear and, to a lesser extent, hierarchical hypertexts. However, the results also showed that during browsing, a mixed text can eliminate the disorientation problems of novices, suggesting that an appropriate text structure may compensate for the learner's lack of a conceptual structure of the domain.

The variables of hypertext topology and knowledge level of the subject can be thought of as manipulations of structure on the one hand and of content on the other. The facilitatory effects of the mixed and, to a lesser extent, hierarchical texts reflect the ease with which the subjects grasp the structure of these texts. The facilitatory effects of prior knowledge reflect a knowledge of the conceptual content of the text. These two variables seem to be partially distinct: while they both improved performance overall, only topology affected navigation as a function of delay.

The comparable effects of the two variables may be because the mixed text, together with the hierarchical text, give clues to conceptual content. For example, the three main branches of the hierarchical and mixed structures reflect the three main themes of the text, which was about three kinds of learning: understanding, memorising and problem solving. This mapping of structure and content was further enhanced in the mixed text because the cross-referential links highlighted significant semantic relationships between themes. For example one link was between the use of prior knowledge in understanding and analogical problem solving. Nevertheless, this mapping was not complete since the mixed text emphasised structural information while prior knowledge concerns semantic relationships.

The distinction between structure and content highlights a key issue for encouraging the effective use of hypertext. This issue concerns how to create text structures and other aids that enable users to access the relevant information for the task in hand. The main problem with hypertext interfaces is that only one node of information can be viewed at any one time (the keyhole phenomenon, Woods (1984); this affects a user's ability to navigate efficiently through hypertext (Watts, 1994). As Wickens (1990) points out (see chapter 2) successful navigation depends upon the existence of correspondences among the physical representation of the world (and the traveller's position therein), the traveller's egocentric view of the world, (what is seen in the forward field of view) and the traveller's mental representation of the world. When these correspondences are broken disorientation occurs. Therefore, we need to develop aids that can help users gain an overview of the material. A mixed text is likely to facilitate navigation because it allows more rapid access to needed information than does a hierarchical text and because it also places greater constraints on the search process than does a pure non-linear hypertext. Other aids are likely to be effective if they have similar characteristics.

The results also showed that navigation performance was correlated with spatial ability for both knowledgeable and non-knowledgeable subjects. Thus spatial ability seems to be a good predictor of navigation performance.

Finally, while the results show facilitatory effects of hypertext topology I do not wish to claim that structural manipulations are the only ways to facilitate navigation. Another common device is to provide the user with a navigational aid, such as a map of the text's spatial structure, or a contents list. Indeed the correlations found between spatial skills and navigation performance seem to suggest that a spatially based navigational aid might facilitate navigation. The usefulness of such aids in relieving user disorientation is examined in the next chapter (chapter 6).

SUMMARY

In summary, the results show that disorientation is a problem for hypertext users especially those unfamiliar with the subject matter of the text, who cannot rely upon their existing prior knowledge to help them structure the text. The problem also seems to be particularly marked when non-linear texts are used. A mixed text, by contrast, considerably eases the disorientation problem as does a hierarchical text, although to a lesser extent. However, modifications in text structure are not the only way in which navigation can be improved, there are a number of different navigational aids that can be used. The aim of experiments 5 and 6 is to evaluate the effectiveness of two of the more popular aids, the spatial map and the contents list.

6

Supporting navigation in hypertext

INTRODUCTION

The fact that users seem to have difficulty in finding their way through hypertext may be related to the type of spatial knowledge they have of the document, and the way in which this knowledge was acquired. From navigation we acquire route knowledge, and from maps we acquire more advanced survey knowledge (Thorndyke and Hayes-Roth 1982). The most common way people get to know their environment is through direct navigational experience of that environment. However, while the knowledge acquired from navigation may ultimately lead to the development of a superior mental representation or cognitive map, it is very difficult to obtain, and takes some considerable time to develop. Wickens (1985) suggests that a short cut to the development of survey knowledge might be achieved through map study.

These observations are of particular importance for hypertext. First, it is often the case, that in the situations where hypertext is employed, for example in information retrieval, users need to acquire survey knowledge about their environments very quickly. In other words it is not practical or even possible for them to gain survey knowledge of the environment by extensive navigation experience. Second, hypertext is by nature a very irregular environment, consequently, navigation alone may not be the most efficient way to obtain a well developed cognitive map. Therefore, it may be the case that the development of survey knowledge in hypertext users might be enhanced if they are given the opportunity to study a map of the database. This study tests these ideas by comparing the performance of subjects who are allowed direct navigational experience (referred to as the browsing group) in hypertext, with a group of subjects who are given a map of the system's structure to learn.

The study also examines the relationship between spatial knowledge and subject prior knowledge. Experiment 4 (chapter 5) demonstrated a relationship between domain knowledge and subjects' ability to navigate efficiently through hypertext. Specifically, subjects with prior knowledge of the topic of the text demonstrate more efficient navigation than subjects with low prior knowledge. This difference in performance may have arisen because knowledgeable subjects already have a conceptual map of the text, which they can use to guide choices concerning where to look for information. It may be the case that this conceptual knowledge can facilitate the development of a survey type representation of the physical layout of the text. Therefore it is necessary to examine how domain knowledge interacts with the means by which subjects get to know locations in hypertext. If it is the case, that a "conceptual map" can facilitate the construction of a spatial map of the text, then knowledgeable subjects should perform better than non-knowledgeable subjects, particularly in the browsing condition. It is also predicted that map learners, regardless of level of prior knowledge, will perform better than browsing subjects, and that subsequent navigation performance will be correlated with the subjects' ability to represent the hypertext as a cognitive map.

Experiment 6 examined the effects of presenting users with an on-line map of the hypertext compared with a text based navigation aid. Specifically, the aim of the 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, and on subjects' ability to represent the document structure as a cognitive map. The study also seeks to examine the relationship between navigational aids and domain knowledge. 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 produce more accurate cognitive maps and demonstrate superior browsing and navigation performance.

EXPERIMENT 5

METHOD

Subjects

Twenty four student volunteers from Durham University served as subjects and were paid for their participation. Half of the subjects had prior knowledge of the subject matter of the text (knowledgeable subjects), the other half had minimal prior knowledge (non-knowledgeable subjects). Their ages ranged from 18 to 31 years. All subjects had some previous experience of using computers. Subjects were tested individually.

Materials

The non-linear hypertext used in experiment two was used for this study. In addition, a numbered alphabetical list of all of the nodes contained in the document along with a complete map of the hypertext document with node titles was used for the cognitive map task, along with an outline map of the document, omitting the node titles.

Design

The experiment used a 2 x 2 factorial design. The independent variables were; training condition, map learning or browsing; and knowledge level; knowledgeable and non-knowledgeable. The dependent variables were the subject's ability to represent the hypertext's structure as a cognitive map, point directions, estimate route distances, (measures of spatial knowledge) and, their ability to use the hypertext to locate seven target nodes, (measure of navigation performance). In addition the subjects' score on the cognitive map task was correlated with their performance on the card location task.

Each subject was assigned to one of the two experimental conditions, map learning and browsing. Half of the subjects in each condition were knowledgeable subjects , and half were non-knowledgeable. Subjects were allowed twenty-five minutes to either learn the map, or browse through the hypertext document. Subjects were then required to make orientation judgements (direction pointing and distance estimates). After that, subjects were required to represent the document's structure as a cognitive map, and use the hypertext document to locate seven target nodes. Finally, subjects completed a pre-test questionnaire on their previous computer experience.

Procedure

In order to ensure that subjects had equivalent experience of using computers, subjects were asked to complete a pre-test questionnaire on their previous computer experience. Specifically, subjects were asked how long they had been using computers, and what packages they had used. Subjects were also asked to give ratings on a five point scale on how comfortable they felt using computers. The scale ranged from very comfortable to very uncomfortable. Five points were awarded for a rating of very comfortable, and one point was awarded for a rating of very uncomfortable.

Both subject groups received initial tuition on how to move around in hypertext. Subjects were then assigned to one of the two experimental conditions; map learning or browsing. Subjects in the map learning condition were given a complete map with node titles of the hypertext document to learn. Subjects were allowed to draw the map out on scrap paper in order to help them learn the document's structure. Subjects in the browsing condition were instructed to browse through the hypertext document, and try to see as much of the document as they could. They were told to pay particular attention to how the document appeared to be structured. Subjects in both conditions were allowed twenty five minutes for this task. Any questions the subject had were answered before the experiment began. After this initial training period measures of spatial knowledge and navigation performance were obtained from subjects in both experimental conditions. The measures of spatial knowledge were direction pointing, distance estimation and a cognitive map task.

In the direction pointing task subjects were taken to a specified node within the hypertext document. They were asked to indicate from a choice of hypertext links contained in that node, which they would select in order to travel to another target node, which in some instances could be quite distant form the source node. This procedure was repeated over ten trials, each trial used different target and source nodes. The mean number of correctly identified links was recorded for each subject. In the distance estimation task subjects were asked to estimate the distance in terms of the number of nodes that would need to be opened in order to get from a given source node to a target node. Specifically, subjects were given two node titles printed on a piece of card. They were asked to estimate how many nodes they would have to open in order to get from the first node to the second. Each subject made ten such estimates. The task was scored in terms of the number of nodes deviating from the correct distance.

In the cognitive map task each subject was presented with an outline map of the hypertext document, without the node titles, and a numbered alphabetically ordered list of all the hypertext nodes contained in the document. Subjects were instructed to mark the numbers corresponding to the nodes on the list in the correct places on the map.

Subjects were encouraged to perform this task as accurately as they could and were asked not to guess. The total number of correct placements was calculated for each subject.

The navigation measure consisted of a card location task. Subjects were instructed to navigate through the hypertext document in order to locate seven target nodes. Subjects were instructed to follow the most direct route they could through the document. 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. Subjects started their search from the node at which they had made their last response. The number of nodes opened over and above the minimum needed to locate each target card was recorded. No additional search facilities were incorporated into the hypertext document. Subjects had to traverse the hypertext links in order to reach their desired location. The subjects' performance on this task was correlated with their score on the cognitive map task. A list of the target cards used can be found in Appendix D.

RESULTS

Pre-test questionnaire

The subjects in the study had comparable levels of computer experience: knowledgeable subjects (mean = 3.8 years); non-knowledgeable subjects (mean = 4 years). In addition all subjects rated themselves as feeling comfortable using computers: knowledgeable subjects (mean rating = 4.6), non-knowledgeable subjects (mean rating = 4.7).

Measures of Spatial Knowledge

Direction pointing

The number of correctly identified links was recorded for each subject. Table 6.1 presents the mean number of correctly identified links. The maximum achievable score was 10.

Table 6.1
Mean number of correct responses in the direction pointing task for experiment 5

	Map Learning	Browsing
Non-knowledgeable subjects	9.3	7.2
Knowledgeable subjects	9.2	7.3

A 2 x 2 ANOVA revealed a significant main effect of training condition only, ($F(1,20) = 23.6$, $p < 0.001$). Subjects in the map learning condition were better able to judge the direction of target nodes.

Distance estimation task

Subjects were asked to estimate the distance in terms of the number of nodes that would need to be opened in order to get from a given source node to another target node. The task was scored in terms of the number of nodes deviating from the correct distance. For example, if the correct distance from node A to node B is 7, and the subject gave a distance estimate of 6, then the difference score would be 1. Similarly, if the subjects had estimated 8 then their score would also be 1. The lower the score the better or more accurate the estimate. Subjects made ten estimates, and the mean difference score was calculated for each subject. Table 6.2 presents the mean difference scores for both non-knowledgeable and knowledgeable subjects in the map learning and browsing condition.

Table 6.2

Mean difference scores for the distance estimation task for experiment 5

	Map Learning	Browsing
Non-knowledgeable subjects	3.5	6.9
Knowledgeable subjects	3.2	4.3

A 2 x 2 ANOVA revealed significant main effects of training condition ($F(1,20) = 28.6$, $p < 0.001$), and knowledge level ($F(1,20) = 12.1, p < 0.01$), and a significant interaction between them ($F(1,20) = 7.4, p < 0.01$) . Tests of simple main effects revealed that map subjects performed better than browsing subjects at both knowledge levels (knowledgeable: $F(1,20) = 3.5, p < 0.07$; non-knowledgeable: $F(1,20) = 32.6, p < 0.01$). However, knowledgeable subjects performed better than non-knowledgeable subjects in the browsing condition only (browsing: $F(1,20) = 19.3, p < 0.01$; map: $F(1,20) = 0.3, p < 1$).

Map task

Table 6.3 presents the mean number of correctly placed node titles for subjects in the map learning and browsing condition. A 2 x 2 ANOVA revealed a significant main effect for training condition only, ($F(1,20) = 36.5$, $p < 0.001$). Subjects in the map learning condition placed significantly more correct node titles than subjects in the browsing condition.

Table 6.3
Mean number of correctly placed node titles for the cognitive map task for experiment 5

	Map Learning	Browsing
Non-knowledgeable subjects	19.2	7.5
Knowledgeable subjects	19.3	7.2

Navigation Performance

Card location task

The mean number of additional nodes opened over and above the minimum needed to locate each target card was calculated for each subject. Table 6.4 presents the mean number of additional nodes opened by subjects for the card location task.

Table 6.4
Mean number of additional nodes for the card location task for experiment 5

	Map Learning	Browsing
Non-knowledgeable subjects	2.9	7.0
Knowledgeable subjects	2.5	4.5

A 2 x 2 ANOVA revealed significant main effects of both training condition ($F(1,20) = 60.08$, $p < 0.001$), and knowledge level ($F(1,20) = 12.7$, $p < 0.002$) and a significant interaction between them ($F(1,20) = 7.3$, $p < 0.01$) . Tests of simple main effects revealed that map subjects performed better than browsing subjects at both knowledge levels (knowledgeable: $F(1,20) = 12.8, p < 0.002$; non-knowledgeable: $F(1,20) = 54.6, p < 0.001$). However, knowledgeable subjects performed better than non-knowledgeable subjects in the browsing condition only (browsing: $F(1,20) = 19.6$, $p < 0.001$; map: $F(1,20) = 0.4, p < 1$).

Correlation Measures

The number of additional nodes opened to locate the seven target nodes, and the subject's scores on the cognitive map task were subject to a Pearson's correlation analysis. The result was a negative correlation between the two measures ($r = -0.64$, $n=24$), which was significant at the 0.05 level. As the subjects cognitive map score increased, (the better the map) the number of additional nodes opened by the subjects decreased, demonstrating more efficient navigation behaviour.

DISCUSSION

These results demonstrate that the use of a map leads to the development of a cognitive map and better navigation performance more expeditiously than does direct navigation experience through browsing, and that any subsequent navigation performance is dependent upon the development of a cognitive map. The knowledge level of the subject also influenced the results. In the distance estimation task and in the navigation task, knowledgeable subjects performed better than non-knowledgeable subjects, but only in the browsing condition.

The results of the card location task showed that the navigation performance of subjects in the map condition was superior to that of subjects in the navigation condition. Specifically, subjects in the map condition opened fewer additional cards over and above the minimum needed to locate each target card than subjects in the navigation condition. Subjects in the map condition were better able to plan and execute routes through the document because they had a more advanced survey type representation of the hypertext. Moreover, subjects in the map condition correctly place more node titles than subjects in the browsing condition. Moreover, the subject's ability to navigate through hypertext was positively correlated with their ability to represent the document's structure as a cognitive map. In other words, the navigation performance of those subjects with better developed cognitive maps was superior to that of subjects with low cognitive map scores. These findings support and extend those of Edwards and Hardman, (1989) and Simpson and McKnight (1990). Edwards and Hardman found that knowledge of hypertext structure was positively correlated with subjects' self reports of feeling lost, as assessed by a questionnaire. Our results amplify these findings by demonstrating that knowledge of hypertext structure is positively correlated with subjects' actual navigation performance.

The poorer performance of subjects in the navigation condition however, implies that these subjects were relying upon landmark and route knowledge to guide their explorations of the document. Consequently, these subjects were often unable to reach their desired location either because they made a wrong turn, that is selected an incorrect node, in which case their route knowledge will have been rendered useless, or because they had not yet travelled along the required route to the target card and so had no knowledge of that particular route through the hypertext.

The results also showed that the performance of knowledgeable subjects was superior to that of non-knowledgeable subjects. Thus, prior knowledge in the subject matter can facilitate navigation through hypertext. This result is consistent with those of McGrath, (1992), and Shin, et al, (1994), who also found that non-knowledgeable subjects are impaired in their reading and understanding of hypertext documents, particularly non-linear documents. Undoubtedly, the expert's superior navigation abilities arise because they have an understanding of the conceptual organisation of the subject matter, which can allay some of the disorientation problems that arise with hypertext. However, the results also showed that map study can eliminate the disorientation problems of non-knowledgeable subjects.

Turning not to the spatial knowledge that was acquired, the results showed that with distance estimation the use of a map also eliminated the difference due to knowledge level that was found in the browsing condition. On the other hand, the direction pointing and the cognitive map task showed no effect of knowledge level. What might account for this differential effect of knowledge level? One possibility is that effects of prior knowledge were masked by ceiling effects in direction pointing and the cognitive map task. However, this possibility seems unlikely. While performance of both subject groups was close to ceiling on direction pointing this was far from the case with the cognitive map task. A more plausible possibility, therefore, is that in learning the map subjects have developed a mental representation of the nodes and their titles, although the relationships between the nodes may well be unspecified. With such a mental map subjects therefore, can derive the answers to the direction pointing questions by inspecting this representation directly. They can complete the cognitive map task by retrieving the titles they have learned for each node. By contrast, distance estimation requires that the links between each node be fully specified in the mental representation, a degree of specificity that is unlikely to be achieved. This lack of specificity in the mental representation may explain why Thorndyke and Hayes-Roth found that considerably more direct navigation experience was needed for distance estimation to improve compared to direction pointing.

A similar degree of specificity is needed for efficient navigation. Subjects are unlikely to be able to go to a target node by the most direct route unless all the links between the nodes are specified in the mental representation. In these circumstances prior knowledge of the subject matter may compensate for the lack of a fully specified mental representation of the hypertext. Armed with a conceptual understanding of the topic, knowledgeable subjects can infer where the links are likely to be on the basis of already known semantic relationships between concepts discussed in different parts of the text. Thus, distance estimation and navigation are facilitated by prior knowledge in the browsing condition. The corollary of this is that allowing non-knowledgeable learners the opportunity to understand the spatial layout of hypertext might compensate for their lack of conceptual knowledge of the subjects matter. Indeed, knowledge of the spatial layout may convey some conceptual structure in its own right.

Therefore, it seems that the provision of a map especially for those unfamiliar with the knowledge domain, may accelerate the development of a cognitive map of the hypertextual space which they can use to guide their subsequent navigation through the document. Consequently, map learners are able to navigate through the document more efficiently than browsing subjects. This is probably due to the irregularity of the environment and to the fact that spatial knowledge is harder to acquire from navigation alone (Thorndyke and Hayes-Roth (1982). However, these results do not suggest that maps lead to the development of a superior cognitive representation than direct experience in an environment. They simply imply that, in an irregular environment such as hypertext, where the nature of the task often requires users to be able to locate and retrieve information efficiently and quickly, a map might assist users in their struggle to form a coherent cognitive map of the document layout.

EXPERIMENT 6

METHOD

Subjects

Thirty six student volunteers from Durham University served as subjects. Half of the subjects were knowledgeable subjects in the subject domain of the hypertext, the other half were non-knowledgeable. All subjects had equivalent computer experience. Subjects were tested individually.

Materials

The same document was used as in the previous study. Three hypertext conditions were used (map, contents list and basic hypertext). In the map condition subjects were provided with a localised spatial map of the document (see figure 6.1 for an example). The document was too large to be displayed on screen in its entirety, therefore a selection of localised mini maps were used, that displayed the area of the document subjects were in at any one time. In the contents list condition subjects were provided with a scrollable contents list of all of the nodes in the hypertext (see figure 6.2 for an example). 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.

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 time taken to locate the answers, (measures of navigation); the subject's ability to represent the hypertext's structure as a cognitive map (measure of structural knowledge); and the number of times each navigational tool was used during reading and question answering, Each subject was randomly assigned to one of the three experimental conditions (map, contents list, raw hypertext). Subjects were required to

Figure 6.1

An Example of a section of a localised spatial map

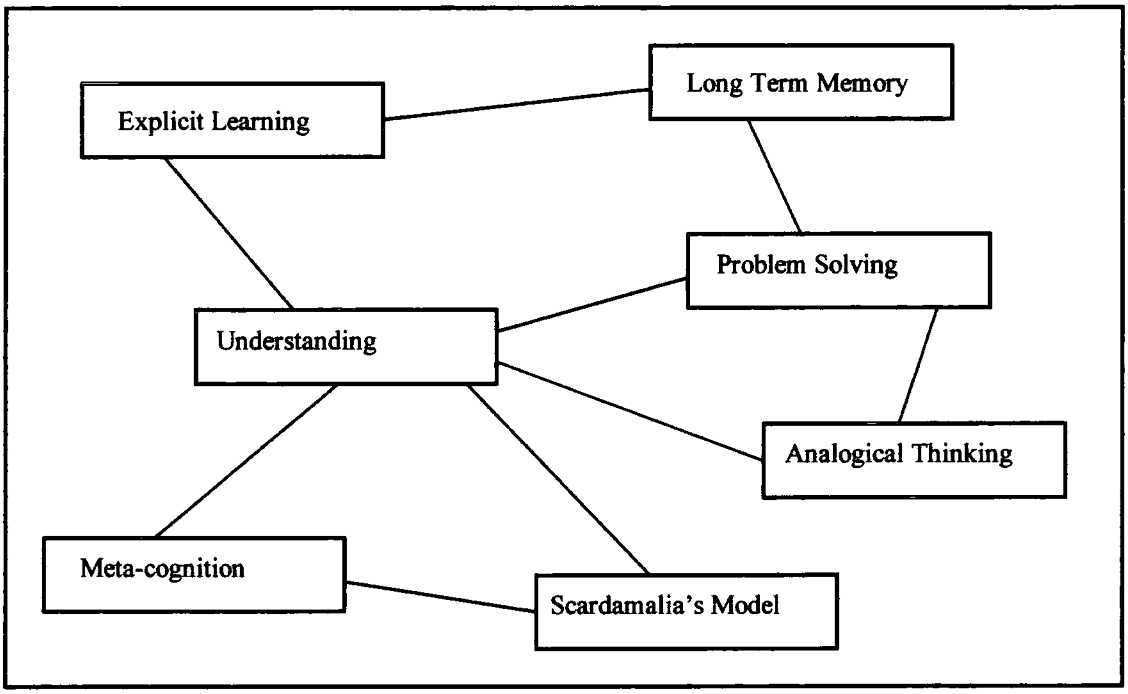


Figure 6.2

An example section of the contents list

Contents List

Learning as Understanding
Scardamalia and Bereiter's model
Metacognition
Analogical Thinking
The Pragmatic Model of Analogical Thinking
Structural Constraints
Semantic Constraints
Pragmatic Constraints
Learning as Problem Solving

read through the hypertext until they thought they had viewed the whole document. The subjects used the document to find the answers to ten questions. A full list of the questions used in this experiment can be found in Appendix D. Subjects then completed a cognitive map task. Finally, subjects were given a copy of the disorientation questionnaire used in experiments 1 and 2 to complete.

Procedure

At the start of the experiment subjects were asked to complete a questionnaire on their computer experience. To ensure an equivalent level of interaction each subject then read a computerised tutorial which explained how to use the hypertext document. The tutorials were tailored for the type of navigational aid the subjects used during the experiment. Any questions the subject had were answered before the experiment began.

In order to familiarise themselves with the hypertext the subjects were instructed to read through the hypertext until they thought they had seen the whole document, using the navigational tool (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 tool (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. Subjects then completed a cognitive map task in which they were given an outline map of the hypertext with a numbered alphabetical list of all the nodes in the document. Subjects were instructed to mark the numbers corresponding to the list in the correct places on the map. The number of correct placements was recorded for each subject. Finally, subjects completed a post test questionnaire examining user disorientation.

RESULTS

Reading

Number of different cards opened:

Table 6.5 presents the mean number of different nodes opened during reading in each condition for both non-knowledgeable and knowledgeable subjects.

Table 6.5
Mean number of different and repeated nodes opened during reading, as a function of level of prior knowledge and navigational aid for experiment 6

	Hypertext		Contents List		Map	
	K	**NK**	**K**	**NK**	**K**	**NK**
Different Nodes	21.3	15.3	32.7	24.8	40.5	38.5
Repeated Nodes	5.5	6.8	4.3	6.2	2.5	3.0

K = Knowledgeable
NK = Non-knowledgeable

A between subjects ANOVA revealed two significant main effects: navigational aid, ($F(2,30) = 60.0$, $p < 0.001$), and prior knowledge, ($F(2,30) = 11.2$, $p < 0.001$). Tukey HSD tests indicated significant differences between all three subject groups. (hypertext vs. contents list: $Q(2,30) = 7.6$, $p < 0.01$; hypertext vs. map: $Q(2,30) = 15.5$, $p < 0.01$; contents list vs. map: $Q(2,30) = 7.9$, $p < 0.01$) 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 navigational aid and prior knowledge.

Number of repeated nodes

The second row of Table 6.5 presents the mean number of nodes opened repeatedly for each condition for both non-knowledgeable and knowledgeable subjects. A between subjects ANOVA revealed two significant main effects: navigational aid, (F(2,30) =

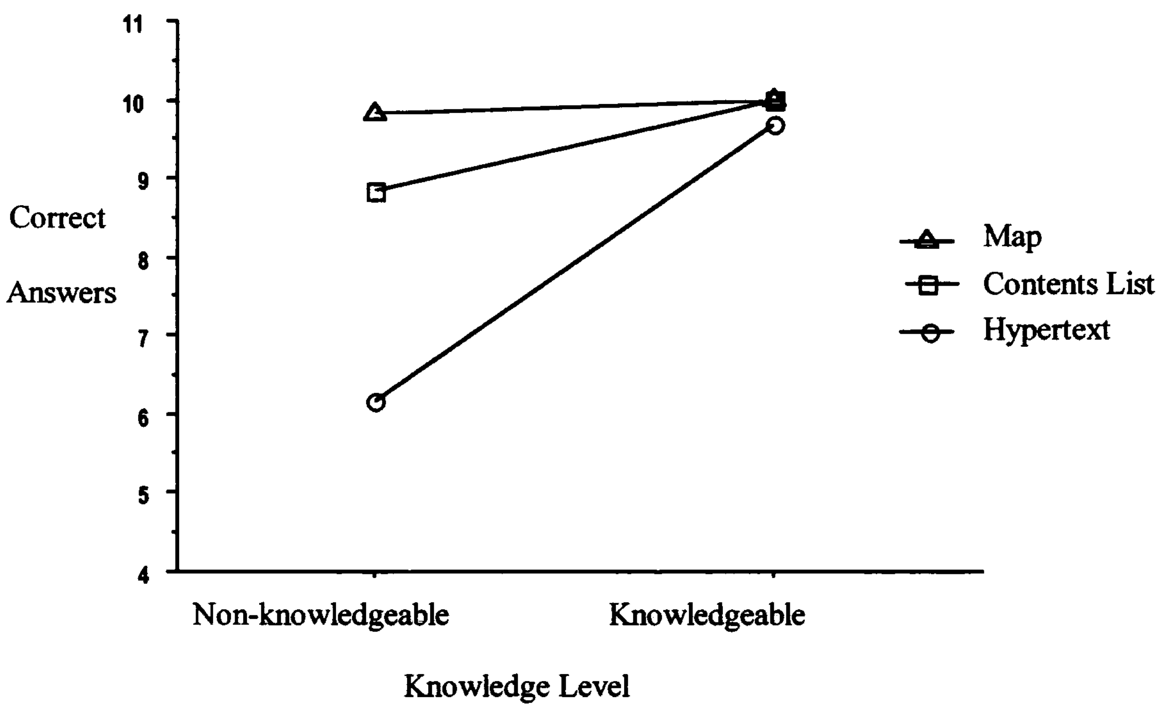
17.6, $p < 0.001$), and prior knowledge, ($F(2,30) = 6.3$, $p < 0.001$). Tukey HSD tests indicated significant differences between the map condition and the other two conditions only. (hypertext vs. map: $Q(2,30) = 8.1$, $p < 0.01$; contents list vs. map: $Q(2,30) = 5.9$, $p < 0.01$; hypertext vs. contents list: ($Q = 2.2$) 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 navigational aid and prior knowledge.

Navigation

Correct answers:

Figure 6.3 presents the mean number of correct answers.

Figure 6.3
Mean number of correct answers as a function of prior knowledge and navigational aid for experiment 6



A between subjects ANOVA revealed two significant main effects: navigational aid, ($F(2,30) = 19.7$, $p < 0.001$), and prior knowledge, ($F(1,30) = 35.3$, $p < 0.001$). There were fewer correct answer in the hypertext condition than in the other two conditions, and knowledgeable subjects answered more questions correctly (mean = 9.9) than non-knowledgeable subjects, (mean = 8.3). There was also a significant interaction ($F(2,30) = 13.3$, $p < 0.01$). 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: $F(1,30) = < 1$). There was also a significant effect of navigational aid for non-knowledgeable subjects ($F(2,30) = 32.6$, $p < 0.01$), but not for knowledgeable subjects ($F(2,30) = < 1$). 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: $Q(2,30) = p < 1$).

Time taken:

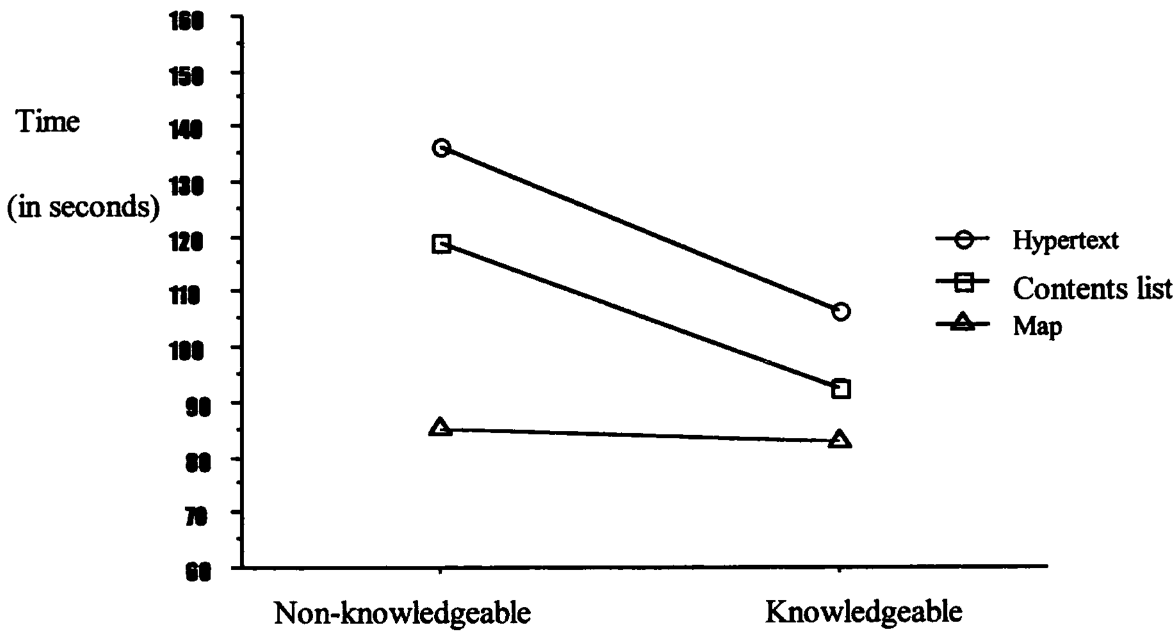
The mean time to answer the ten questions was calculated for each subject. These means are shown in Figure 6.4.

A between subjects ANOVA revealed a main effect of navigational aid, ($F(2,30) = 25.1$, $p < 0.001$), times were fastest with the map, next fastest with the contents list and slowest with the basic hypertext, and a main effect of prior knowledge, ($F(2,30) = 20.3$, $p < 0.001$). Knowledgeable subjects (mean = 93.8) found the answers faster than non-knowledgeable subjects, (mean = 113.6).

However, these main effects were modified by a significant interaction between the two variables ($F(2,30) = 3.9$, $p < 0.02$). Tests of simple main effects revealed that for the hypertext and contents list condition the performance of knowledgeable subjects was superior to that of non-knowledgeable subjects (hypertext: $F(1,30) = 15.7$, $p < 0.001$; contents list $F(1,30) = 12.5$, $p < 0.002$). However there was no difference in performance between non-knowledgeable and knowledgeable subjects in the map condition (map: $F(1,30) = 0.1$, $p < 1$ ns). They also revealed that there was a significant effect of navigational aid for both non-knowledgeable subjects and knowledgeable subjects (non-knowledgeable: $F(2,30) = 24.1$, $p < 0.001$; knowledgeable subjects $F(2,30) = 5.0$, $p < 0.01$). Non-Knowledgeable subjects found the answers faster in the map condition, than in the contents list condition, who in turn found the answers faster than subjects in the hypertext condition. (hypertext vs. map: $Q(2,30) = 9.62$, $p < 0.01$; hypertext vs. contents list: $Q(2,30) = 3.23$, $p < 0.01$; contents list vs. map: $Q(2,30) =$

6.39, $p < 0.01$). Knowledgeable subjects in the map and condition found the answers faster than subjects in the hypertext condition.(hypertext vs. map: Q(2,30) = 4.45, $p < 0.01$). However there was no difference between subjects the contents list condition and the other two conditions. (contents list vs. map: Q(2,30) = 1.86, *ns;* hypertext vs. contents list: Q(2,30) = 2.59, *ns*).

Figure 6.4
Mean time to answers questions as a function of prior knowledge and navigational aid for experiment 6



Additional cards:

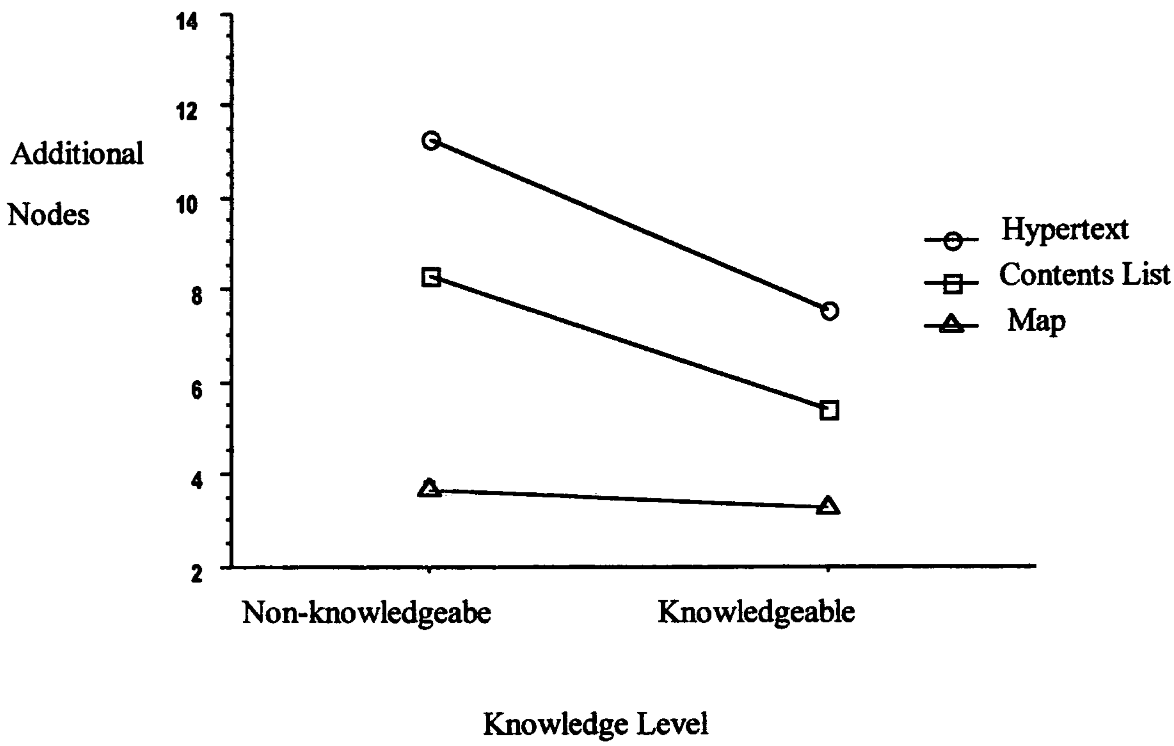
The mean number of additional nodes opened to find each answer was calculated for each subject. These means are shown in Figure 6.5.

A between subjects ANOVA revealed significant main effects of navigational aid, ($F(2,30) = 50.3$, $p < 0.001$), and prior knowledge ($F(1,30) = 23.3$, $p < 0.001$) Subjects in the map condition opened fewer additional cards than subjects in the contents list condition, who in turn, opened fewer additional cards than subjects in the hypertext condition. Knowledgeable subjects (mean = 5.4) opened fewer additional nodes than non-knowledgeable subjects, (mean = 7.7).

However, these main effects were modified by a significant interaction between the two variables ($F(2,30) = 4.2$, $p <0.02$).

Figure 6.5

Mean number of additional nodes opened as a function of prior knowledge and navigational aid for experiment 6



Tests of simple main effects revealed that for the hypertext and contents list condition the performance of knowledgeable subjects was superior to that of non-knowledgeable subjects (hypertext: $F(1,30) = 19.4, p < 0.001$; contents list $F(1,30) = 12.1, p < 0.002$). However there was no difference in performance between non-knowledgeable and knowledgeable subjects in the map condition (map: $F(1,30) = 0.23, p < 1$ ns). They also revealed that there was a significant effect of navigational aid for both non-knowledgeable subjects and knowledgeable subjects (non-knowledgeable: $F(2,30) = 41.49$, $p < 0.001$; knowledgeable subjects $F(2,30) = 13.0$, $p < 0.001$). Non-Knowledgeable subjects opened fewer additional cards in the map condition, next fewest in the contents list condition and next fewest in the hypertext condition (hypertext vs. map: $Q(2,30) = 11.25, p < 0.01$; hypertext vs. contents list: $Q(2,30) = 4.91, p < 0.01$; contents list vs. map: $Q(2,30) = 7.86, p < 0.01$). Knowledgeable subjects opened fewer additional cards in the map condition, next fewest in the contents list condition and next fewest in the hypertext condition (hypertext vs. map: $Q(2,30) = 7.21$, $p < 0.01$;

hypertext vs. contents list: Q(2,30) = 3.59, $p < 0.05$; contents list vs. map: Q(2,30) = 3.62, $p < 0.01$).

Use of the navigational aid

The number of times subjects used the navigational tools during reading and information retrieval were recorded. Table 6.6 presents the mean number of times each navigational aid was used during reading and information retrieval by both non-knowledgeable and knowledgeable subjects.

Table 6.6
Mean number of times navigational aids were used during browsing and information retrieval for experiment 6

	Knowledgeable		Non-Knowledgeable	
	Browsing	Information Retrieval	Browsing	Information Retrieval
Map	9.8	6.5	16.3	12.0
Contents list	8.7	6.2	11.2	11.7

A three factor repeated measures ANOVA revealed significant main effects of navigational aid ($F(1,20) = 19.3$, $p<0.003$), prior knowledge ($F(1,20)= 157.2$, $p < 0.0001$), and task type browsing or information retrieval, ($F(1,20)= 10.8$, $p < 0.001$). The main effect of navigational aid arose because subjects in the map condition used their navigational 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 navigational 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)

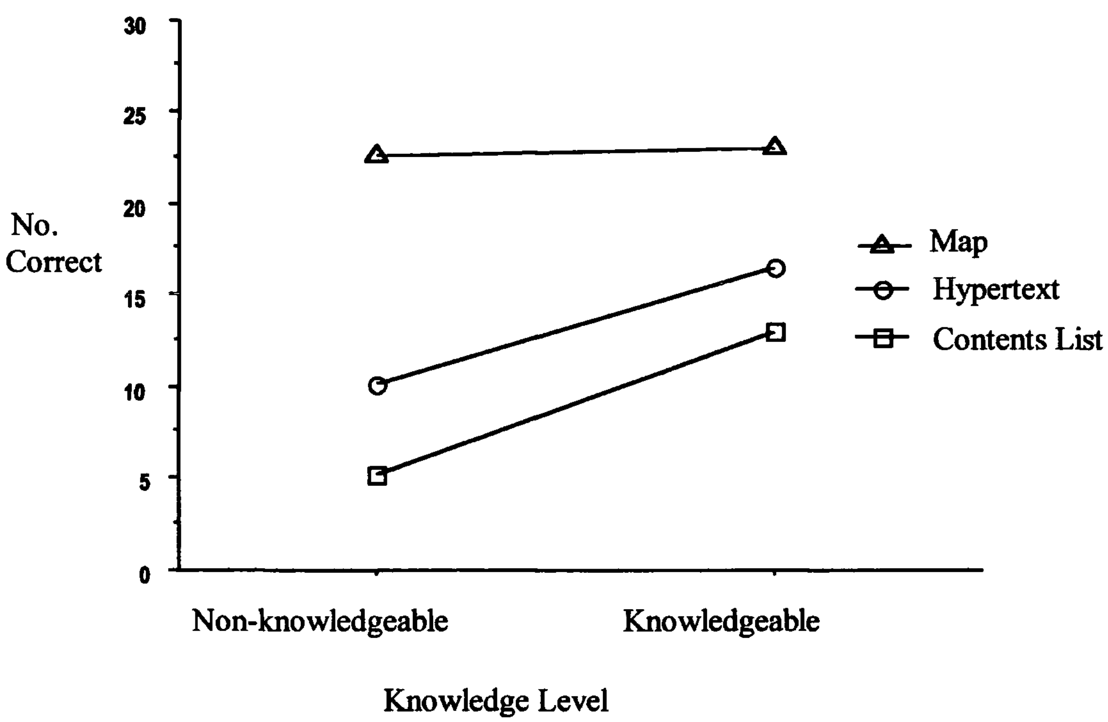
However, there was also a significant interaction between navigational aid and prior knowledge. ($F(1,20) = 6.3$, $p < 0.02$). This interaction modified the main effect of navigational aid. Non-Knowledgeable subjects used the map significantly more times than the contents list. However there was no difference between the number of times knowledgeable subjects used the map and contents list .

Structural Knowledge

Cognitive map task

Figure 6.6 presents the mean number of correctly placed node titles for all three subject groups for both non-knowledgeable subjects and knowledgeable subjects. The maximum achievable score was 45.

Figure 6.6
Mean number of correctly placed node titles for the cognitive map task as a function of prior knowledge and navigational aid for experiment 6



A between subjects ANOVA revealed two significant main effects: navigational aid, ($F(2,30) = 50.9$, $p < 0.001$), and prior knowledge, ($F(1,30) = 17.9$, $p < 0.001$). Subjects in the map condition placed more correct node titles than subjects in the hypertext condition, who in turn, placed more correct node titles than subjects in the contents list condition. Knowledgeable subjects placed more correct node titles (mean = 17.5) than non-knowledgeable subjects, (mean = 12.7)

There was also a significant interaction between navigational aid and prior knowledge, ($F(2,30) = 4.0$, $p < 0.03$). Tests of simple main effects revealed that for the hypertext and contents list condition the performance of knowledgeable subjects was superior to that of non-knowledgeable subjects (hypertext: $F(1,30) = 10.3$, $p < 0.003$; contents list $F(1,30) = 15.8$, $p < 0.002$). However there was no difference in performance between non-knowledgeable and knowledgeable subjects in the map condition (map: $F(1,30) = 0.03$, $p < 1$ ns). They also revealed that there was a significant effect of navigational aid for both non-knowledgeable subjects and knowledgeable subjects (non-knowledgeable: $F(2,30) = 41.7$, $p < 0.001$; knowledgeable subjects $F(2,30) = 13.2$, $p < 0.001$). Non-Knowledgeable subjects made fewest correct placements in the contents list condition, next fewest in the hypertext condition, and next fewest in the map condition, (hypertext vs. map: $Q(2,30) = 9.1$, $p < 0.01$; hypertext vs. contents list: $Q(2,30) = 3.6$, $p < 0.05$; contents list vs. map: $Q(2,30) = 17.5$, $p < 0.01$). Knowledgeable subjects made fewest correct placements in the contents list condition, next fewest in the hypertext condition, and next fewest in the map condition, (hypertext vs. map: $Q(2,30) = 4.7$, $p < 0.01$; hypertext vs. contents list: $Q(2,30) = 2.5$, $p < 0.05$; contents list vs. map: $Q(2,30) = 7.2$, $p < 0.01$).

Questionnaire data

The disorientation questionnaire used in experiments 1 and 2 was also used for this study. Table 6.7 presents the total scores per condition for the disorientation scale. The higher the score the greater the perceived disorientation.

Table 6.7

Mean scores for the disorientation questionnaire for xperiment 6

	Hypertext		Contents List		Map	
	K	**NK**	**K**	**NK**	**K**	**NK**
Disorientation score	37.5	42.5	26.0	37.3	21.3	28.3

K = Knowledgeable
NK = Non-knowledgeable

A between subjects ANOVA revealed significant main effects of navigational aid, ($F(2,33) = 29.4$, $p < 0.001$) and prior knowledge ($F(2,33) = 23.1$, $p < 0.001$) 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 less feelings of disorientation than subjects in the hypertext condition. Knowledgeable reported fewer feelings of disorientation (mean score = 28.3), than non-knowledgeable subjects (mean score = 36.1)

DISCUSSION

These results indicate that in general, both knowledgeable subjects 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* (1988) and Simpson and McKnight, (1990). 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 support 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 (1989) and Dee-Lucas and Larkin (1995) 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 subjects and non-knowledgeable subjects on all three measures, accuracy, the time taken to answer the questions, 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 map 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. These findings concur with those of Monk, Walsh and Dix, (1988) and Simpson and

McKnight, (1990) 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.

There was no effect of navigational aid on the correct answers of the knowledgeable subjects This is probably due to a ceiling effect. The questions were not very difficult because we were primarily concerned with discovering how easily the subjects could find the answers, not with whether they could answer the questions having found the information. However, non-knowledgeable subjects in the hypertext condition did rather poorly in answering the questions, indicating that non-knowledgeable subjects find it difficult to learn the structure of the text in the absence of a navigational aid.

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 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 no on the reading measures. Reading was facilitated for both non-knowledgeable 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 (experiments 1-4), 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.

Subjects in the map condition also produced more accurate cognitive maps than subjects in the contents list condition, who in turn produced more accurate maps than subjects in the basic hypertext condition. These findings contrast with those of Wenger and Payne, (1994) who found that the provision of a map had no reliable effect on a subject's structural knowledge of hypertext. The discrepancy in these findings may be accounted for by the fact that Wenger and Payne used a much simpler task. Subjects were given pairs of node titles and were asked to decide if the nodes were linked in the text. In addition, the text used was very short, making it less likely that differences would be observed. Stanton *et al* (1992) also found that a map resulted in poor development of a cognitive map. This discrepancy may also be accounted for by task differences. Stanton *et al's* subjects were instructed to draw their cognitive maps free-hand. Whereas our study required subjects to label on outline map of the hypertext. This method was chosen because research has shown (see for example, Blaut and Stea, 1974) that sketch maps may not adequately represent a person's knowledge because of limitations in their drawing ability

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, deciding which routes will satisfy their information goals, executing these routes, keeping track of digressions as well as monitoring 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 what is more interesting is the difference in performance of subjects in the map and contents list condition. The performance of non-knowledgeable subjects in the map condition was superior to their performance in the contents list condition, on all the measures taken. Knowledgeable subjects performance was also better with the map than the contents list on the measures of reading and on the cognitive map task. One reason for these differences in performance between the two aids might be 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, allows users to plan and execute routes through the document, thus encouraging the development of survey knowledge.

The development of spatial knowledge progresses from knowledge of landmarks and the routes that connect them, to a more elaborate survey type representation. Although direct navigational experience in an environment will in time, eventually lead to the development of such a representation, researchers such as Wickens (1985) Moeser, (1988) and Hirtle and Hudson (1991) suggest that a short cut to survey knowledge may be achieved through map study. The findings of the present study support this argument. The poorer performance of subjects in the pure hypertext and to a lesser extent the textual contents list conditions suggests that these subjects may have been relying upon landmark and route knowledge to guide their explorations of the document. Consequently, these subjects were often unable to reach their desired location either because they made a wrong turn, that is, selected an incorrect node, in which case their route knowledge will have been rendered useless, or because they had not yet travelled along the required path to the target card and so had no knowledge of that particular route. Subjects in the map condition however, demonstrated more efficient navigation behaviour, and were able to follow more direct routes through the document, they also produced more accurate cognitive maps of the text structure. This suggests that these subjects had acquired a more survey type of representation which allowed them to work out more direct routes or short cuts to the information they required, and meant that if they did become lost or side tracked they had a greater chance of re-gaining their bearings.

These findings have two important implications for hypertext. First of all, they suggest that the type of navigational aids employed should be matched the background knowledge of the user, that is, non-knowledgeable users seem to benefit most from a spatially organised map, and knowledgeable subjects benefit equally from a map and a textual contents list. 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 with the provision of navigational aids, especially with a localised map. However, as Gupta and Gramopadhye (1994) 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.

In conclusion, it appears that the navigation performance of hypertext users improves when they are given access to navigational tools. Both non-knowledgeable subjects and knowledgeable subjects benefit from a contents list and a map. However, the provision of a localised spatial map seems to eliminate some of the problems typically associated with user disorientation, and is especially effective in the case of non-knowledgeable subjects.

SUMMARY

The results of experiments 5 and 6 suggest that the use of maps as navigational aids are of benefit to users, at least in terms of information retrieval. However, the utility of such spatially based tools to support learning in hypertext as opposed to navigation still needs to be examined empirically. The experiments presented in chapter 8 examine the effectiveness of maps in supporting learning in hypertext.

7

Hypertext and learning

INTRODUCTION

The general aim of the experiments that follow in this chapter is to examine the effects of non-linear text on learning. The results of the preceding experiments presented in chapters 4 - 6 have shown that subjects experience navigational problems or disorientation in hypertext, especially when a complex non-linear text with many links is used. On the face of it, these results suggest that a linear text is preferable to a hypertext document for presenting learning materials. 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 (1992) 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. They suggest that long term retention and transfer may be increased by creating difficulties for the learner during acquisition. Mayes, Kibby, and Anderson, (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.

As regards learning from text, Kintsch (1994) also suggests that learning may be increased by forcing readers to engage more actively with text. He suggests that factors which serve to simplify the comprehension process may hamper long term learning because the reader does not have to actively process the text to extract its meaning. It may be that hypertext's complexity and possible lack of coherence may also increase learning because it forces readers to engage more actively in the processing of the text. Indeed as Rouet and Levonen (1996) point out, in linear text the reader can passively follow the organisation proposed by the author. In hypertext however, progression through the text requires active decision making. After reading a node, the reader must select another node in order to progress.

However, previous studies conducted by Gordon et al (1988) and Foltz (1993) have failed to show any learning benefits for hypertext. Indeed, Gordon et al concluded that hypertext can disrupt both reading and learning. However, there are methodological problems with both of these studies which limit our ability to draw clear cut conclusions from them. In contrast to most real-world learning situations, the subjects in these studies knew that they had to read the whole text and that everything they needed to learn would be available in that text. The subjects also used a list from which they selected topics to read, or in the case of Foltz and interactive overview diagram, which is much simpler than having to make sense of a complex non-linear network of embedded text links. In addition, the texts used were quite small, and the experimenters did not control for the effects of prior knowledge of the text topic.

The experiments reported in this chapter were designed to asses the effects of non-linear hypertext on both short term and long term learning, compared to a linear version of the same document. Experiment 7 served as a pilot study. The study examined the effects of a linear text and a non-linear hypertext on short term learning with a specific goal. Experiment 8 examined both short term and long term learning in hypertext compared to a traditional linear text. Subjects were tested not only immediately after acquisition but a week later as well. The learning tasks used in this study include measures of memory for text and measures of understanding. If it is the case that hypertext does induce the reader to engage in active processing then we would anticipate the performance at retention will be superior in the hypertext condition. However, according to Kintsch (1994) and McNamara et al (1996), those learners who lack background knowledge of the text topic may not benefit from text induced active processing because they do not have the necessary background knowledge upon which to draw when making the necessary bridging inferences. Experiment 9, therefore compares the performance of readers with and without background knowledge of the text topic. It is predicted that overall, the performance of knowledgeable subjects will be superior to that of non-knowledgeable subjects, and that knowledgeable subjects will demonstrate superior performance with hypertext. Measures of navigational efficiency were also included in these studies to see if there was a relationship between good navigation and good learning. In other words, to examine whether the texts which lead to efficient navigation also lead to better learning.

EXPERIMENT 7

METHOD

Subjects

Forty undergraduate volunteers from the university of Durham served as subjects. Their ages ranged from 19 to 25 years. All subjects had previous experience of using computers. At the start of the experiment all subjects were unfamiliar with the concepts and ideas discussed in the experimental text.

Materials

The hypertext document used in this study was called "Steam Locomotives" written by Adam Davidson. This text-based document presented a discussion of the history and design of British Steam Locomotives. The text consisted of 3500 words and was presented on 35 individual cards. The text was specifically written for use as an experimental stack. The construction and arrangement of the stacks was carried out at the time of writing. The text was implemented in HyperCard 2.2 by the present author. The text was presented in two formats. A traditional linear text and a non-linear hypertext. Each document contained the same information but had a different structure. The linear document had a sequential structure, in which 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 hypertext 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. Subjects moved through the hypertext by clicking on text buttons. The document also included a backtrack facility. The documents were implemented using HyperCard 2.2. A copy of the text can be found in Appendix B.

Design

The experiment used a between subjects design. The between subjects factor was text organisation (linear or hypertext). The dependent variables included measures of reading and learning. The reading measure was the time spent reading. The learning measures were the number of factual questions correctly answered, and the number of main ideas questions correctly answered. Subjects studied the experimental text in order to fulfil a pre-stated learning goal. Subjects then answered questions pertaining to that learning goal.

Procedure

Before the experiment began subjects were asked to answer twenty questions about the information contained in the experimental text. These questions were scored immediately by the experimenter. Only those subjects who scored less than 20% of the questions correct were used as subjects. This measure was taken in order to minimise the effects of prior knowledge.

Subjects were then randomly assigned to one of the two text conditions, and worked through a tutorial on how to use the computerised document. Subjects then studied the text for a period of up to 1 hour. They were however, allowed to quit the document when they felt they had reached an understanding of the text and would be able to satisfy their learning goal. Each subject was given the following learning goal. *"Describe how the design of steam engines changed to meet the needs of a rapidly expanding railway network."* It was decided to give subjects this general goal rather than instructing subjects to learn the whole text, because it was considered that this type of task was more similar to that of a real world learning situation, and would also help us to assess if subjects could independently determine what information they should read. Although, this general goal required subjects to explore relationships between various parts from the text, it does not explicitly specify which parts of the text they should focus on.

After this initial learning period subjects were required to answer questions about the text. Half of the questions tapped memory for factual information. For example, *"Which locomotive hauled the first train?"*. The remaining questions required a more deeper understanding of the text. For example, *" What is the purpose of the blast pipe, and how does it relate to steam generation and consumption ?"* The answers to these questions were scored as correct if they could be considered to be a paraphrase of the correct answer. The subjects were allowed freedom of expression, but the main points had to be present. Scoring was done in collaboration with the text author. Ambiguous responses were discussed and resolved. Subjects answered in writing, without time restrictions. The number of correct answers given were recorded for each subject. A full list of the questions used in this study can be found in Appendix E.

RESULTS

Reading Measures

Time Spent Reading:

The time spent on reading (in minutes) by subjects in both text conditions was:- linear 37.9 hypertext 40.5. An independent samples t-test revealed that there was no significant differences between the two groups (df = 18, t = -0.84, $p < 1$).

Learning Measures

Factual Questions:

The mean number of factual questions answered by subjects in both text conditions is presented in Table 7.1. One point was awarded per correct answer. The maximum achievable score was 20. An independent samples t-test revealed a significant difference between the two groups (df = 18, t = 3.9, $p < 0.01$). Subjects in the linear condition answered more questions correctly than subjects in the hypertext condition.

Table 7.1
Mean number of factual questions and main point questions answered correctly - Experiment 7

	Linear	Hypertext
Mean number of factual questions answered correctly	17.0	12.7
Mean number of main point questions answered correctly	16.7	14.3

Main Ideas Questions:

The mean number of main point questions answered by subjects in both text conditions is presented in Table 7.1. Out of 7 questions the maximum achievable score was 20. . Partial credit was given when appropriate. An independent samples t-test revealed a significant difference between the two groups (df = 18, t = 2.6, $p < 0.02$). Subjects in the linear condition answered more questions correctly than subjects in the hypertext condition.

DISCUSSION

The results showed that subjects in the linear condition answered more factual and main ideas questions correctly than subjects in the hypertext condition. These results support those of Gordon et al (1988), who also found that hypertext can disrupt learning, and more general studies conducted by Gray, 1987; Johansen and Tennyson, 1983; Kieras, 1985, who found that high learner control does not lead to more superior learning.

Taken together, these results seem to imply the learning suffered in hypertext as a consequence of the navigational problems experienced by the subjects in the hypertext condition. However, it is important to note that this experiment only examined short term learning. The learning tests were administered immediately after the subjects had read the experimental text, that is, immediately after the acquisition phase of learning. Schmidt and Bjork (1992) argue that experimental variables may have two distinct effects on learning. First, they may have a relatively permanent effect, (true learning). Second, they may have a more transient effect that serves to enhance or diminish performance differences while the variables are still in operation. Such effects, may rapidly disappear in the absence of the experimental variables or if the subject is allowed to rest. Consequently Schmidt and Bjork argue that performance levels during acquisition are flawed with respect to the amount learned, and advocate the use of retention tests some time after the initial experiment. The following study therefore, examines learning both immediately after the acquisition phase and again after a retention phase of one week. This measure was incorporated into the study in order to evaluate the extent to which true learning has taken place.

EXPERIMENT 8

METHOD

Subjects

Twenty four volunteers from the university of Durham served as subjects. Their ages ranged from 18 to 35 years. All subjects had previous experience of using computers. At the start of the experiment all subjects were unfamiliar with the concepts and ideas discussed in the experimental text.

Materials

The text used in this study was called "Data Structures in Jackson Structured Programming". This document presented a discussion of the Jackson Structured Programming and focused on the use and production of data structure diagrams. The text was written specifically for use as a hypertext document by the present author. Each document contained the same information but had a different structure. The structures examined in this study were a traditional linear text, and a non-linear hypertext. 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 hypertext 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. Subjects moved through the hypertext by clicking on text buttons. The document also included a backtrack facility. The hypertext document was 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 twelve lines of New York 16 pt text. The test document consisted of 30 individual cards. The document was displayed using a 14 inch Macintosh colour monitor. A copy of the text can be found in Appendix C.

Design

The experiment used a between and within subjects mixed factorial design. The between subjects factor was text organisation, (linear or hypertext). The within subjects factor was test phase, (acquisition or retention). The dependent variables were the time spent on reading, the number of factual questions correctly answered, and the number of problems correctly solved during acquisition and retention.

Subjects were instructed to try and learn the experimental text. During the acquisition phase the subjects were required to answer twenty questions about the content of the text. Subjects were then required to solve five problems using data structure diagrams. After a period of one week subjects returned to the laboratory to complete a retention task.

Procedure

Before the experiment began subjects were asked to answer twenty questions about the information contained in the experimental text. These questions were scored immediately by the experimenter. Only those subjects who scored less than 20% of the questions correct were used as subjects. This measure was taken in order to minimise the effects of prior knowledge.

After initial tuition on how to use the computerised document, subjects were instructed to read through, and to try and understand the experimental text. Once the subjects felt they had understood the whole document they were asked to answer several questions about the text. Subjects answered ten questions in all. For example, *"Name and draw the three main constructs used in JSP"*. Subjects answered in writing, without time restrictions. The number of correct answers was recorded for each subject. Finally, subjects were given a set of five problems to solve, in which they had to draw data structure diagrams. One point was awarded for each correctly drawn item. For example, *"A customer file is sorted by region code. There are a number of regions in the file and there could be any number of records per region. Draw the data structure of this file"*.

One week later subjects returned to the laboratory to complete a retention test consisting of a further set of questions, and a further five problems to solve. The number of correct answers was recorded for each subject. The subject answers were scored in the same way as the acquisition phase. Subjects were told that a second visit to the laboratory was necessary so that they could complete a reading speed test and other comprehension measures. The real purpose of the visit was concealed from them in order to minimise the possibility that they might try to rehearse the material during the retention phase. All subjects were thoroughly debriefed at the end of the experiment. A full list of the questions and problems used in this study can be found in Appendix E.

RESULTS

Reading

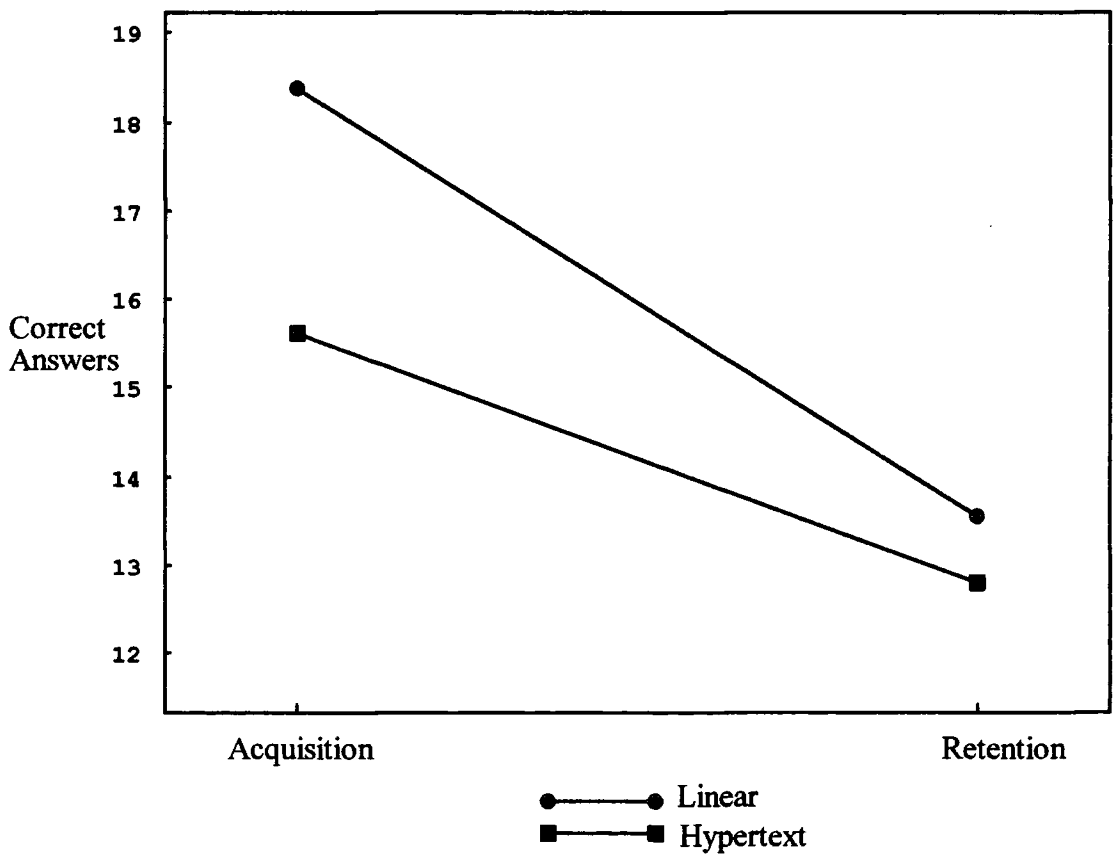
Time spent reading

The time spent on reading in minutes by subjects in each condition was:- hypertext 39.58; linear text 38.33. An unpaired t-test revealed that the difference between the two groups was not significant (df = 22, t = -0.59, $p < 0.56$).

Factual Questions:

Figure 7.1 shows the mean number of factual questions correctly answered by subjects in both text conditions for both test phases. Out of ten questions the maximum achievable score was 20 (some questions were worth more than one point).

Figure 7.1
Mean number of factual questions answered - Experiment 8



A between and within subjects ANOVA revealed significant main effects of: text organisation ($F(1,22) = 6.9$, $p<0.02$) and test phase ($F(1,22) = 76.6$, $p<0.001$). Subjects in the linear condition answered more questions correctly than subjects in the hypertext condition. Subjects also answered more questions correctly during acquisition than at retention

There was also a significant interaction between text organisation and test phase ($F(1,22) = 5.2$, $p<0.05$). Tests of simple main effects revealed that performance was better at acquisition than at retention regardless of text condition (linear: ($F(1,22) = 60.9$, $p < 0.001$; hypertext $F(1,22) = 20.9$, $p < 0.01$). During acquisition subjects in the linear condition answered more questions correctly than subjects in the hypertext condition ($F(1,22) = 11.9$, $p<0.001$). However at retention there was no difference in the number of questions correctly answered by subjects in the linear and hypertext conditions ($F(1,22) = 0.9$, $p<1$).

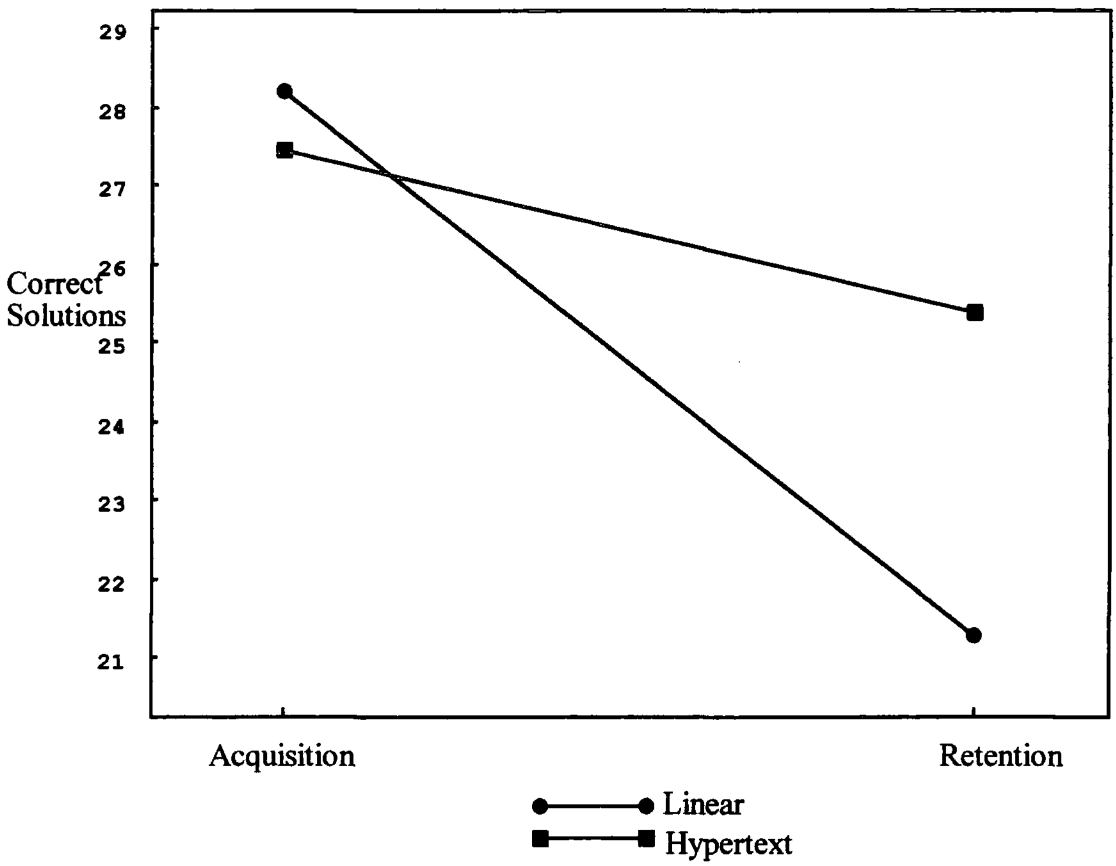
Problem Solving Questions:

Figure 7.2 shows the mean number of problems correctly solved by subjects in both text conditions for both test phases.
A between and within subjects ANOVA revealed a significant main effect of test phase ($F(1,22) = 64.5$, $p<0.001$). Subjects solved more questions correctly in test phase 1 (acquisition) than in test phase 2 (retention).

However, there was also a significant interaction between test phase and text organisation ($F(1,22) = 18.6$, $p<0.001$). Tests of simple main effects revealed that performance was better at acquisition than at retention regardless of text condition (linear: ($F(1,22) = 76.6$, $p < 0.001$; hypertext $F(1,22) = 6.9$, $p < 0.02$). During acquisition, there was no difference in the number of problems solved by subjects in the hypertext and linear condition ($F(1,22) = 0.3$, $p<1$). However, at retention subjects in the hypertext condition solved more questions correctly than subjects in the linear condition ($F(1,22) = 8.1$, $p<0.01$).

Figure 7.2

Mean number of problem solving questions correctly answered - Experiment 8



DISCUSSION

In general, the results show that at the acquisition phase of learning subjects performed better in the linear condition than in the hypertext condition. However, at retention, this difference in performance was reversed.

With the textual questions, subjects in the linear condition performed better than subjects in the hypertext condition during acquisition. However, at retention there was no difference between the two groups. This is because the hypertext subjects showed less forgetting than the linear text subjects. Thus, when true learning is measured at retention rather than learning contaminated by performance effects at acquisition, the previously reported poor learning in hypertext (Gordon et al 1989) is not upheld.

When learners are tested by giving them problems to solve, the hypertext subjects perform better than the linear subjects after a delay, while there is no difference in performance at acquisition. This result arises because of the marked drop in performance of the linear subjects after a delay.

Taken together, these results suggest that the more challenging the test either because of a delay, or because of the type of questions used (textual or problem solving), the better the drop of the hypertext subjects compared to the linear text subjects.

EXPERIMENT 9

METHOD

Subjects

Thirty two volunteers from the university of Durham served as subjects. Their ages ranged between 22 and 38 years. All subjects had previous experience of using computers. Half of the subjects were postgraduate psychology students who were knowledgeable in the subject matter of the text (knowledgeable). The other half were postgraduate students from a mixture of other disciplines who were unfamiliar with the subject matter of the text (non-knowledgeable).

Materials

The linear and non-linear versions of the experimental text used in experiment 1 (chapter 4) were used in this study. See Appendix A for text.

Design

The same design was used as in experiment 8, except that an additional between subjects factor of prior knowledge (knowledgeable and non-knowledgeable) was included, problem solving questions were not included.

Procedure

The same procedure was used as in experiment 8. However this study also included a navigation search task. After reading, subjects were instructed to navigate through the document in order to locate ten target nodes, taking the most direct route possible. Subjects started their search from the node at which they made their last response. The time taken to locate each node, and the number of additional nodes opened were recorded. Subjects then went on to answer factual questions and main ideas questions at both acquisition and after a retention period of one week. The target nodes used for this experiment an be found in Appendix D, and a list of the learning questions used can be found in Appendix E.

RESULTS

Time spent reading

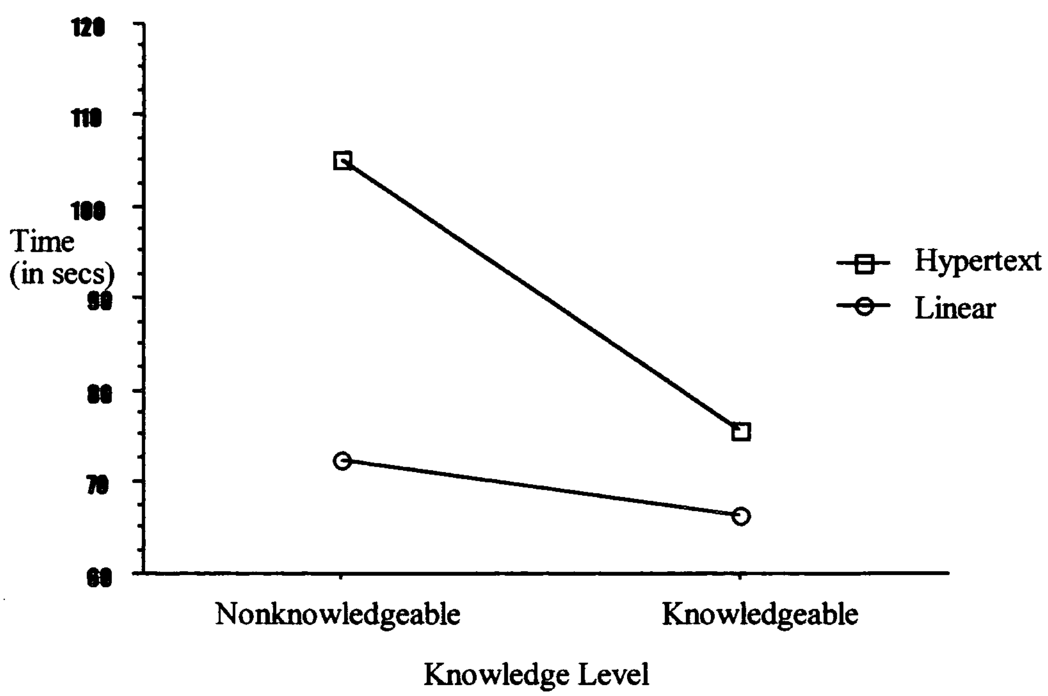
The time spent on reading in minutes by subjects in each condition was:- hypertext 40.06; linear text 39.25. An ANOVA revealed that there were no significant differences between the text conditions ($F(1,28) = 0.308$, $p < 1$), or between non-knowledgeable and knowledgeable subjects ($F(1,28) = 2.5$, $p < 1$)

Navigation

Time Taken: The mean time taken to locate each target node is presented in Figure 7.3.

Figure 7.3

Mean time to locate the ten target nodes as a function of text organisation and prior knowledge - Experiment 9

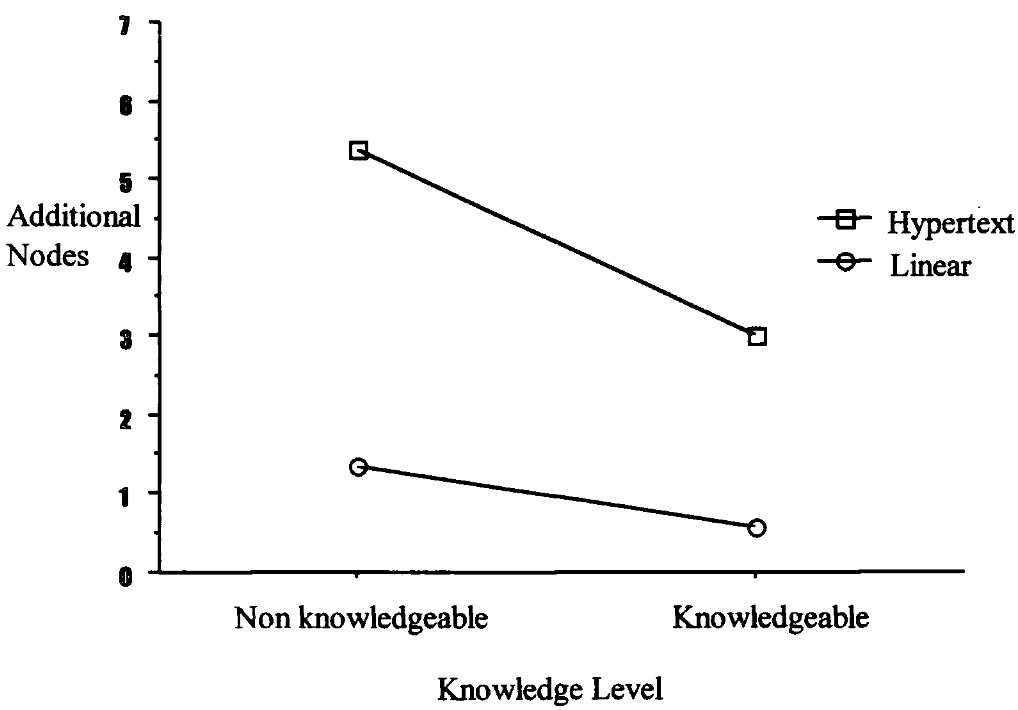


A between subjects ANOVA revealed two significant main effects: text organisation ($F(1,28) = 48.96$, $p < 0.01$), and prior knowledge ($F(1,28) = 34.86$, $p < 0.01$). In general, subjects in the hypertext condition took longer to locate the target nodes than subjects in the linear condition. Non knowledgeable subjects also took longer than knowledgeable subjects. However there was also a significant interaction between the two variables ($F(1,28) = 15.07$, $p < 0.01$). Tests of simple main effects revealed that non-knowledgeable subjects took significantly longer than knowledgeable subjects to locate the ten target nodes in the hypertext condition ($F(1,28) = 47.89$, $p < 0.01$) but not in the linear condition ($F(1,28) =$ $p < 1$).

Additional Nodes: The mean number of nodes opened over and above the minimum needed to locate each target node is presented in Figure 7.4.

Figure 7.4

Mean number of additional cards opened to reach ten target nodes as a function of text organisation and prior knowledge - Experiment 9



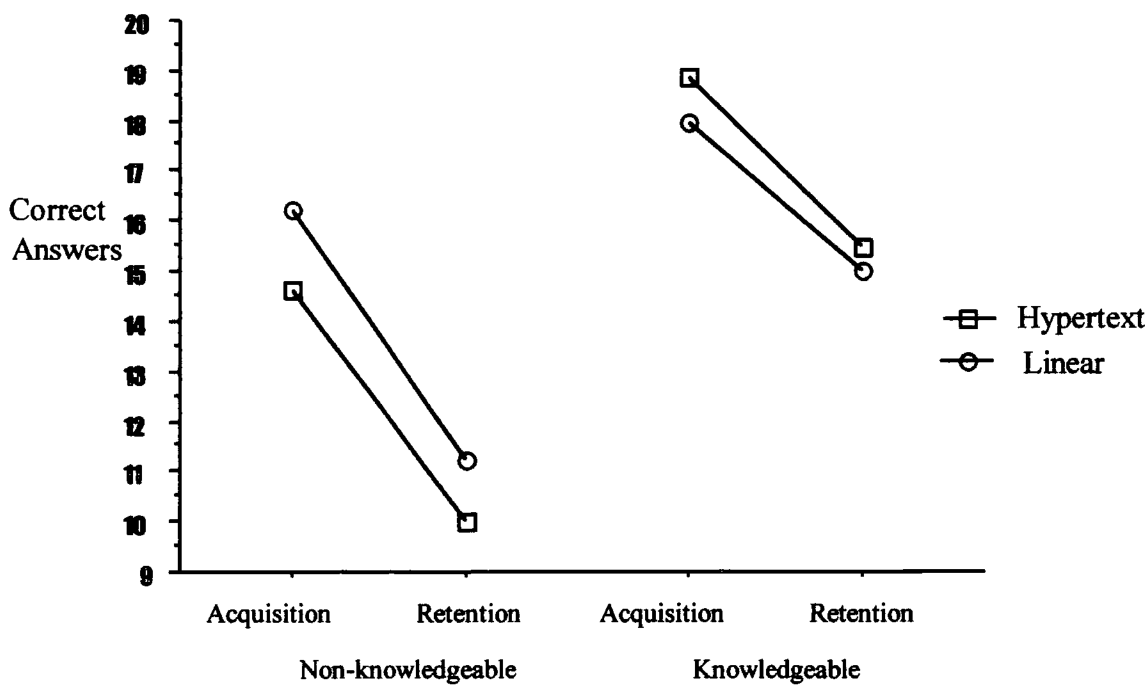
A between subjects ANOVA revealed two significant main effects: text organisation ($F(1,28) = 67.82$, $p < 0.01$), and prior knowledge ($F(1,28) = 16.18$, $p < 0.01$). In general, subjects in the hypertext condition opened more additional nodes than subjects in the linear condition. Non knowledgeable subjects opened more additional nodes than knowledgeable subjects. However. there was also a significant interaction between the two variables ($F(1,28) = 4.17, p < 0.05$). Tests of simple main effects revealed that non-knowledgeable subjects opened more additional cards than knowledgeable subjects in the hypertext condition ($F(1,28) = 18.39, p < 0.01$) but not in the linear condition($F(1,28) = p < 1$).

Learning

Factual Questions: The number of questions correctly answered was recorded for each subject. One point was awarded per correct answer, the maximum achievable score was 20. Figure 7.5 presents the mean number of questions correctly answered for both subject groups.

Figure 7.5

Mean number of factual questions correctly answered as a function of text organisation, prior knowledge and test phase - Experiment 9



A between and within subjects ANOVA revealed two significant main effects: knowledge level ($F(1,28) = 59.27, p < 0.01$), and test phase ($F(1,28) = 81.57, p < 0.01$).

Overall, the performance of knowledgeable subjects was superior to that of non-knowledgeable subjects. Subjects performed better during acquisition than retention.

There was also a significant interaction between knowledge level and text organisation ($F(1,28) = 4.60$, $p < 0.04$). Tests of simple main effects revealed that the non-knowledgeable subjects learned better with the linear text than with hypertext ($F(1,28) = 4.21$, $p < 0.05$). However, there was no difference in performance of knowledgeable subjects using either the linear text or hypertext ($F(1,28) = p < 1$)

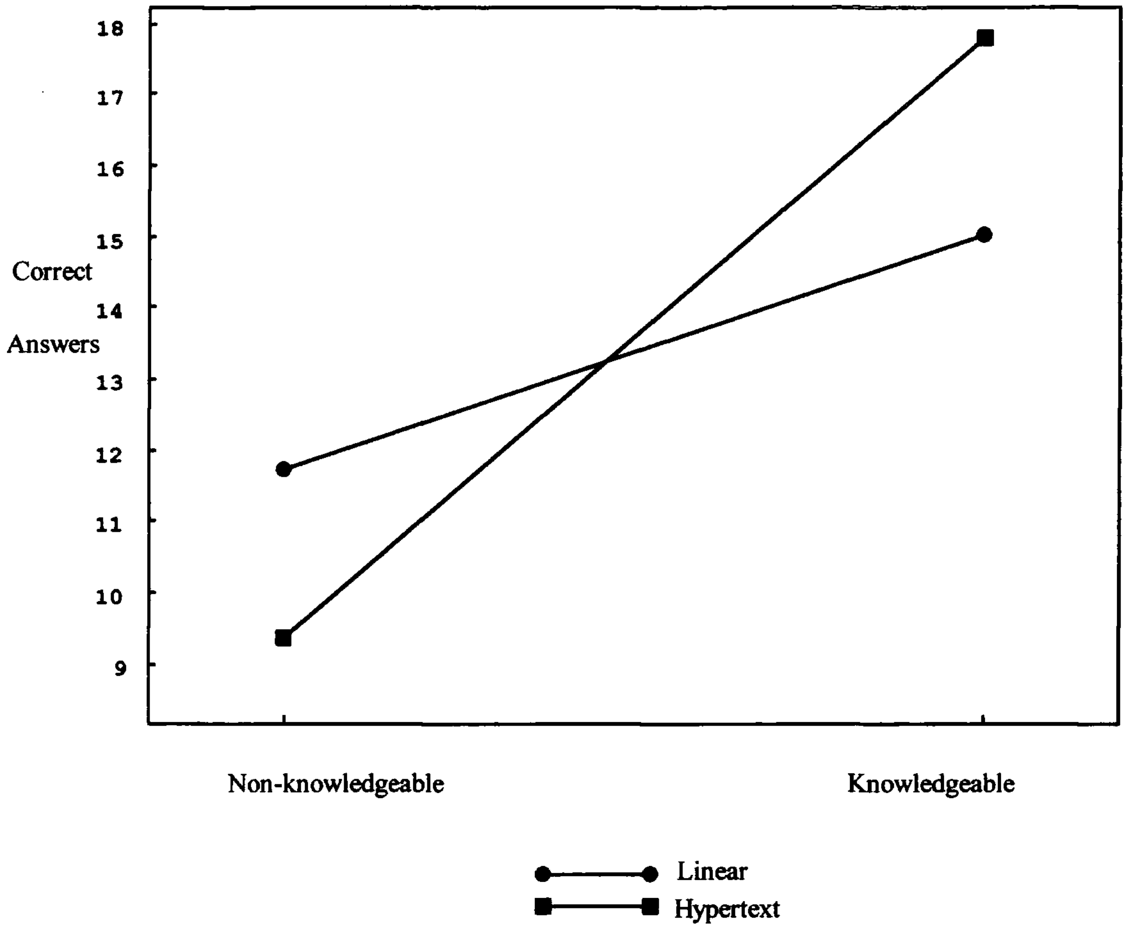
Main ideas Questions: The number of correct answers was recorded for each subject. Each answer was worth a total of two points. Partial credit was given when appropriate. The maximum achievable score was 20.

A between and within subjects ANOVA revealed two significant main effects: knowledge level ($F(1,28) = 193.6$, $p < 0.0001$), and test phase ($F(1,28) = 163.7$, $p < 0.0001$). Overall, the performance of knowledgeable subjects was superior to that of non-knowledgeable subjects. Subjects performed better during acquisition than retention.

There was also a significant interaction between text organisation and knowledge level ($F(1,28) = 36.8$, $p < 0.0001$), and between text organisation and test phase ($F(1,28) = 13.1$, $p < 0.002$). . Figure 7.6 presents the interaction of text organisation and knowledge level. 7.7 presents the interaction of text organisation and test phase. Taking the interaction between text organisation and knowledge level first, tests of simple main effects revealed that for both text conditions knowledgeable subjects performed better than non-knowledgeable subjects (linear: $F(1,28) = 30.8$, $p < 0.0001$; hypertext: $F(1,28) = 199.6$, $p < 0.0001$). However, the performance of knowledgeable subjects was better with hypertext than with the linear text ($F(1,28) = 21.2$, $p < 0.0001$). Non-knowledgeable subjects performed best with the linear text than with hypertext ($F(1,28) = 15.8$, $p < 0.0001$).

Figure 7.6

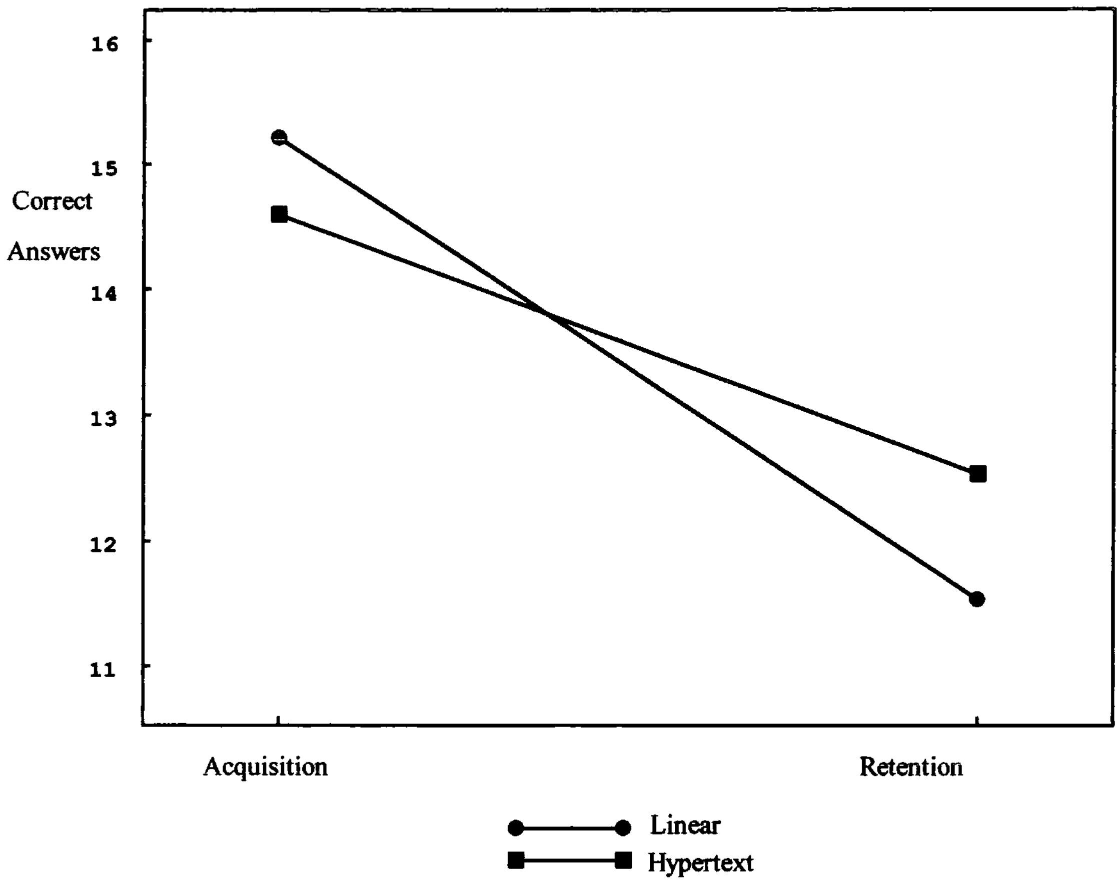
Mean number of main ideas questions correctly answered as a function of text organisation and prior knowledge - Experiment 9



Turning to the interaction between text organisation and test phase, tests of simple main effects revealed that for both text conditions performance was better during acquisition than retention (linear: $F(1,28) = 134.6$, $p < 0.0001$; hypertext: $F(1,28) = 42.1$, $p < 0.0001$). During the acquisition phase there was no difference between the performance of subjects using the linear text or the hypertext ($F(1,28) =$ $p < 1$). However, for the retention phase the performance of subjects in the hypertext condition was superior to that of subjects in the linear condition ($F(1,28) = 4.4$, $p < 0.04$). However, inspection of Figure 7.7 shows that this latter difference is due to the knowledgeable subjects. The three way interaction between text organisation, prior knowledge and test phase was found not to be significant.

Figure 7.7

Mean number of main ideas questions correctly answered as a function of text organisation and test phase - Experiment 9



Discussion

The results demonstrate that in terms of navigation, hypertext users take longer to locate information, and have difficulty in following a direct route to the information they require, when compared to users of a traditional linear text. They also show that subjects who are familiar with the text topic can navigate more efficiently than subjects who are unfamiliar with the text topic. In terms of learning, the results show that the performance of non-knowledgeable subjects is better with linear text than with hypertext. Knowledgeable subjects however, can perform equally well with factual questions or better with main ideas questions when using hypertext. Moreover, the results for the main ideas questions shows that both knowledgeable and non-knowledgeable subjects experience greater forgetting in the linear condition than in the hypertext condition.

GENERAL DISCUSSION

The results of experiment 7 seem to suggest that there is no overall advantage to be gained from the use of hypertext for learning. These findings concur with those of Gordon et al (1988). In fact, these results suggest that learning may suffer in hypertext as a consequence of the navigational problems hypertext creates. However, it would be unwise to dismiss out of hand the use of hypertext for learning based on results such as these. As mentioned previously, performance on short term measures of learning may not give a true representation of the amount learned because the experimental variables may have a relatively transient effect, that serves to enhance or diminish performance differences while the variables are still in operation (Schmidt and Bjork, 1992). Therefore, measures of long term retention are needed. Experiment 8 examined long term retention in hypertext compared to a linear version of the same document. The results of this experiment yielded some interesting findings.

As in experiment 7, during acquisition (immediately after reading the text) the performance of subjects in the linear condition was superior to that of subjects in the hypertext condition. On immediate testing, subjects in the linear condition answered more factual and main ideas questions correctly than hypertext subjects. However, at retention a different pattern of results emerges. For the factual and main idea questions there was no difference in the performance of subjects in the linear and hypertext condition. For the problem solving questions subjects in the hypertext condition answered significantly more questions correctly than linear subjects. The shift between acquisition and retention phases arises because the performance of subjects in the linear condition declines to a greater degree during the retention interval than the performance of hypertext subjects.

So, what might account for these findings? The focus of previous research into learning, and reading to learn has been to identify ways in which we may enhance both the speed and ease of learning. However research reported in Schmidt and Bjork (1992) suggests that variables which serve to maximise performance during acquisition can be detrimental for long term retention. They suggest that introducing difficulties for the learner during acquisition may increase long term performance because the learner will have to engage in more active processing in order to overcome these difficulties. The results of experiment 8 appear to lend support to Schmidt and Bjork's argument. That is, the text which created more navigational difficulties for the learner resulted in better long term retention. In order to progress through hypertext the learner must engage in a process of active decision making. That is, after reading each node the learner must select another node to read out of a number of possible alternatives.

Kintsch (1994) also believes that text induced active processing can be beneficial for leaning. Kintsch suggests that one way to encourage active processing is by disrupting the coherence of the text. A fully coherent text in which the relationships between arguments are expressed in a clear, explicit way will require the reader to make very few, if any, cognitively demanding bridging inferences, and so reduce the amount of active processing. Conversely, a text in which the coherence is disrupted will force readers to engage in more inferential activity, drawing on their prior background knowledge to interpret the incoming text, which may lead to superior learning. Hypertext may also suffer from a lack of coherence because the author may not be able to anticipate every move the reader makes. Indeed it is possible for the hypertext reader to engage in multiple topic shifts which may or may not be signalled. Thus, the hypertext document may have forced readers to engage in more inferential activity in order to maintain coherence.

However, Kintsch (1994) suggests that not all learners may benefit from text induced active processing. In particular those readers who lack background knowledge of the text topic may benefit more from a fully coherent text. Experiment 9 examined the performance of non-knowledgeable and knowledgeable subjects using a traditional linear text or hypertext on both measures of navigation and learning.

The results show that in terms of navigation performance subjects in the linear condition found the target nodes significantly faster, and were able to follow a more direct route through the document than subjects in the hypertext condition. These findings support those of McKnight, Dillon and Richardson (1990) who also found that their subjects performed better using a linear document than hypertext. The results also show that in general, knowledgeable subjects demonstrated superior navigation than non-knowledgeable subjects. However, there was also a relationship between text structure and prior knowledge. On both navigation measures knowledgeable subjects performed better than non-knowledgeable subjects in the hypertext condition but not in the linear condition.

The most likely reason for the superior navigation performance of knowledgeable subjects is that they have an understanding of the conceptual organisation of the subject matter that can allay some of the disorientation problems that arise with hypertext. However, with the linear text the navigation performance of knowledgeable and non-knowledgeable subjects is comparable thus demonstrating that users, particularly, non-knowledgeable users have difficulty in managing the unusually high level of freedom hypertext gives them.

When we turn to the measures of learning a different picture emerges. For the learning of factual material the results showed that knowledgeable subjects performed equally well using either the hypertext document or the traditional linear text. Non knowledgeable subjects, however, performed better with the linear text than with hypertext. The results also show a marked decline in performance by subjects in both text conditions from the acquisition phase of learning to the retention phase.

With the main ideas questions, the results show that at both acquisition and retention, knowledgeable subjects performed better with hypertext than with the linear text. The performance of non-knowledgeable subjects was better with the linear text at acquisition, but comparable for the two texts at retention. This latter results mirrors those for the textual questions in Experiment 8. These findings contrast with those of Gordon et al (1988) who found that hypertext disrupted learning. However, Gordon et al, used a very small text, and only used measures of short term learning. In addition, Gordon et al did not control for the prior knowledge of the learner.

The superior performance of the non-knowledgeable subjects on the linear text is consistent with the findings of Britton and Gulcoz (1991) who found that subjects with low prior knowledge of a text performed better when the text was fully coherent. The superior performance of the knowledgeable subjects who had used the hypertext document on the main ideas questions, and the superior performance of hypertext subjects at retention supports Kintsch's theory of active processing. (Kintsch, 1994). Kintsch suggests that the focus of writing is usually to make the comprehension process easy, to the extent that it requires little mental effort on the part of the reader. However, forcing readers to take a more active role in the comprehension process may help both memory and learning.

Kintsch (1994) distinguishes between two types of memory representation derived from his theory of text comprehension; the textbase and the situational model. The textbase is a representation of what the reader can remember from the text, in terms of the propositions they have encountered. The textbase enables the reader to answer questions about the text, recall the text, and summarise its main points. However, the construction of a text base does not necessarily mean that the user has understood the text. In order for understanding to occur, the reader must actively engage in the processing of the text, forging a link between the new information presented in the text and their prior knowledge about the subject domain. The resulting representation, the situational model, allows the reader to use the new information in novel situations, and, because the text has been integrated with the reader's long term memory, the material learned is less susceptible to the ravishes of time (See also Johnson-Laird 1983). In the present study, two measures of learning were used. The subjects ability to answer factual questions about the text was designed to assess the readers' textbase. The main ideas questions were design to assess conceptual understanding.

Fact learning is a relatively superficial measure of learning. Subjects do not have to understand the concepts in the text in order to remember facts. Therefore we would expect such learning to be quite high during acquisition, just after the text has been read, but to decline rapidly during retention. The results for the fact learning questions showed that knowledgeable subjects performed equally well using either the hypertext document or the traditional linear text. Non-knowledgeable subjects however, performed better with the linear text than with hypertext. Our results also show as expected, a marked decline in performance by subjects in both text conditions from the acquisition phase of learning to the retention phase. These results imply that the text organisation had little effect on text base construction.

One way to simplify the comprehension process, is to maintain coherence in the text. A fully coherent text in which the relationships between arguments are expressed in a clear, explicit way will require the reader to make very few, if any, cognitively demanding bridging inferences. The corollary of this is the formation of a coherent textbase that will enable the reader to answer questions about the text, recall the text, and summarise its main points (McNamara, Kintsch, Butler Songer and Kintsch 1996). However, in order for the reader to acquire a deeper understanding of the text which is less susceptible to forgetting, the reader must actively engage in the processing of the material and develop an adequate situational model. That is, some link must be made with the reader's long term memory. As such the reader's inferential processes play a critical role in the development of understanding. Kintsch suggests that one way to facilitate deeper understanding may be to disrupt the coherence of the text thereby forcing the reader to engage in inferential activity. This may be achieved by failing to specify some coherence relations so that the reader must infer them, omitting certain elaborations in the text, or not clearly signalling the macrostructure of the text (Kintsch, 1994). Kintsch is not suggesting that texts should be purposely disorganised or too difficult for even the most diligent reader. What he is suggesting is that learning may be enhanced if the reader has to actively process the material. Obviously, such texts would be extremely difficult for readers who lack background knowledge of the subject matter of the text. Indeed, Kintsch acknowledges that readers who lack adequate background knowledge will benefit more from a fully coherent and well organised text as demonstrated by Britton and Gulcoz (1991). However, more knowledgeable readers may benefit from the active processing required by less coherent texts. Coherence is likely to be disrupted in hypertext and the results of the main ideas questions show that this disruption results in better learning for both knowledgeable and non-knowledgeable subjects, since their was less of a decline in performance after a delay in the hypertext condition compared to the linear condition. However, as predicted by Kintsch's model, knowledgeable subjects learned best with hypertext while non-knowledgeable subjects learned best with the linear text.

SUMMARY

In summary, subjects appear to experience a number of navigational problems when using hypertext. However, although these problems serve to disrupt learning during acquisition, hypertext can lead to better long term retention.

By contrast, subjects experienced few, if any, navigational problems with the linear text, and demonstrated good performance on the learning measures that were taken immediately after reading. However their performance declined quite markedly during the retention interval. Thus, the text that created difficulties for the learners during acquisition led to better long term retention. These findings lend support to those of Schmidt and Bjork (1992) and Kintsch (1994) who suggest that creating difficulties for the learner during acquisition can lead to better long term retention because they force readers to engage in more active processing. However, as Kintsch (1994) points out, not all learners may benefit from active processing. Indeed the results of experiment 7 have shown that in terms of learning, it appears that non-knowledgeable subjects perform better with a linear text than with hypertext whereas knowledgeable subjects can perform equally well or better with hypertext. However, this is only the case on immediate testing. When delayed testing is used (experiment 8), hypertext subjects perform as well as linear text subjects on comprehension questions and better than linear text subjects at problem solving.

Finally, the results of experiment 9 also showed a dissociation between navigation and learning. While navigation was best with a linear text, learning was more resistant to forgetting with hypertext.

8

Learner control and preferences

INTRODUCTION

Thus far the results of the preceding experiments show that in terms of navigation, hypertext users take longer to locate information, and are less able to follow a direct path to that information that users of a traditional linear text. The results also show that although hypertext may not lead to any learning benefits at acquisition, it can lead to better overall long term retention. However, the preceding experiments presented in this thesis have used between subjects designs. In order to cut down on variability introduced by individual differences experiment 10 re-examines both navigation and learning in hypertext using a repeated measures design. In line with previous findings it is predicted that subjects will demonstrate superior navigation performance with linear text than with hypertext. However, in terms of learning it is predicted that although hypertext may not lead to better learning at acquisition, it will improve long term retention.

A number of ambitious claims have been made with regard to hypertext's potential as a learning environment. As in the case of other programs offering a high degree of learner control, it has been suggested that hypertext promotes a more positive attitude towards instruction, and increases their motivation to learn, minimising the possibility that they may become bored or frustrated because they have the power to skip material they already believe they know or do not wish to learn. Although there is evidence to suggest that hypertext may have a positive effect on both motivation and attitudes towards instruction (Small and Grabowski, 1992; Becker and Dwyer, 1994) these studies have not actually examined learning outcomes as well as motivation. One aim of this study, therefore is to examine both learning and preference for instructional format in situations of high learner control (hypertext) and low control (linear).

EXPERIMENT 10

METHOD

Subjects

Twenty student volunteers from the University of Durham served as subjects and were paid for their participation. Their ages ranged between 19 and 27 years. At the start of the experiment subjects were unfamiliar with the ideas and concepts presented in the experimental texts. Subjects were tested individually.

Materials

The texts used in experiments 7 and 9, presented in chapter 7, were also used in this study. Specifically four texts were used. A linear and hypertext version of the steam locomotives text and a linear and hypertext version of the learning text. See Appendix A for the learning text and Appendix B for the steam text.

Design

The experiment included measures of navigation and learning. The investigation of the effects of text structure on navigation used a between and within subjects design. The within subjects factor was text organisation (linear vs. hypertext); the between subjects factor was text type (steam vs. learning). The dependent variables were; the time spent reading, the mean time taken to locate ten target cards, and the mean number of additional nodes opened to find each sentence.

The investigation into the effects of text structure on learning used a between and within subjects design. The within subjects factors were; text organisation (linear vs. hypertext) and test phase (acquisition vs. retention); the between subjects factor was text type (steam or learning). The dependent variables were the answers to factual and main ideas questions.

Procedure

Before the experiment began subjects were asked to answer twenty questions about the information contained in the experimental texts. These questions were scored immediately by the experimenter. Only those subjects who scored less than 20% of the questions correct were used as subjects. This measure was taken in order to minimise the effects of prior knowledge.

Subjects were informed that they would be reading two texts, a traditional linear text and a hypertext document. After reading the first text, subjects were required to complete a search task. Specifically, subjects were instructed to navigate through the document to locate ten target nodes, taking the most direct route possible. The number of additional nodes opened, and the time taken to locate each target node were recorded. The presentation order for the ten target nodes was randomised for each subject.

Subjects then completed a questionnaire examining disorientation and learning, and had a five-minute break in which they played a computer game. Subjects then read the second text, completed a second search task and another copy of the questionnaire. Five subjects read a linear version of the steam text first followed by a hypertext version of the learning text. Five subjects read the hypertext learning text first followed by the linear steam text. Five subjects read a linear version of the learning text followed by a hypertext version of the steam text, and five subjects read the hypertext version of the steam text followed by the linear version of the linear text (See Table 8.1). A list of the target nodes used for the search task can be found in Appendix D.

Table 8.1

Reading orders for experimental texts - Experiment 10

Group	First Text	Second Text
Group 1	Linear Steam Text	Hypertext Learning Text
Group 2	Hypertext Learning Text	Linear Steam Text
Group 3	Linear Learning Text	Hypertext Steam Text
Group 4	Hypertext Steam Text	Linear Learning Text

After a short break subjects were required to answer questions about the texts they had just read. Subjects answered 20 factual questions and 5 main ideas questions about each text. The order of the questions was counterbalanced across the test phases.

One week later subjects returned to the laboratory to complete a retention test consisting of a further set of questions. Subjects were informed that a second visit to the laboratory was necessary for them to complete a reading speed test. The true purpose of the visit was concealed in order to minimise the possibility subjects might try to rehearse the material during the retention interval. Subjects were thoroughly debriefed at the end of the experiment. A full list of the questions used in this study can be found in Appendix E

RESULTS

Reading

Time spent reading

The time spent on reading in minutes by subjects in each condition was:- linear 36.1; hypertext 37.9. A repeated measures ANOVA revealed that there were no significant differences between the groups for text organisation ($F(1,18) = 1.6, p < 1$) or text type ($F(1,18) = 1.7, p < 1$).

Navigation

Time taken

The top row of Table 10.1 presents the mean time it took subjects to locate the ten target cards. A repeated measures ANOVA revealed a significant main effect of text organisation ($F(1,18) = 48.6, p < 0.01$). Subjects were significantly faster at locating the target cards when they used the linear text than when they used hypertext. There was no effect of text type ($F(1,18) = 0.4, p < 1$).

Additional cards opened

The bottom row of Table 8.2 presents the mean number of additional cards opened by subjects during their search. A repeated measures ANOVA revealed a significant main effect of text organisation ($F(1,18) = 46.2$, $p < 0.01$). Subjects opened significantly fewer additional cards when using the linear text than did when using the hypertext document. There was no effect of text type ($F(1,18) = 3.1, p < 1$).

Table 8.2

Mean time taken and mean number of additional cards opened - Experiment 10

	Linear	Hypertext
Mean time (in seconds)	75.1	97.1
Mean number of additional cards	1.0	4.7

Learning

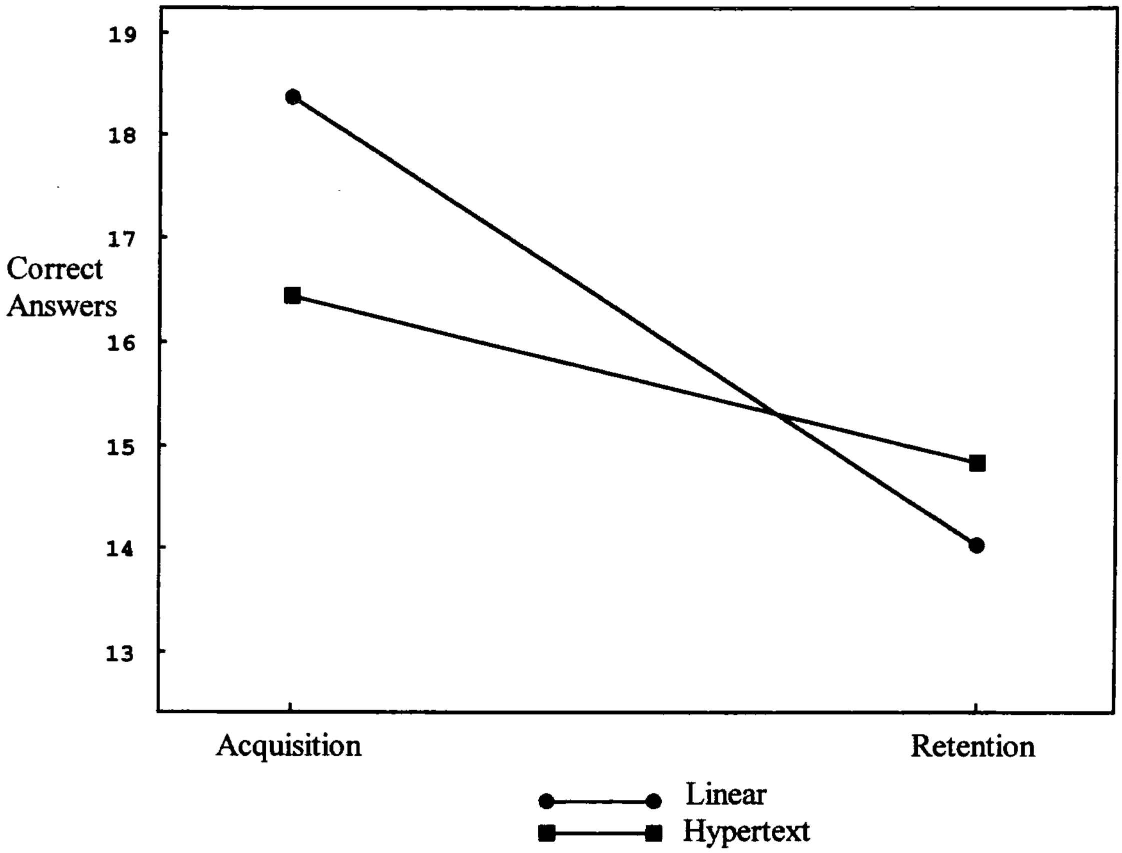
Factual questions

Figure 8.1 presents the mean number of factual questions correctly answered during the acquisition and retention phases. A 2 x 2 ANOVA revealed two significant main effects: text organisation ($F(1,18) = 4.9$, $p<0.04$) and test phase ($F(1,18) = 137.2$, $p<0.001$). The main effect of text organisation arose because subjects answered more questions correctly about the linear text than they had about the hypertext. The main effect of test phase arose because subjects answered more questions correctly during acquisition than during retention. There was no effect of text type ($F(1,18) = 1.1$, $p < 1$).

However there was also a significant interaction between the two variables ($F(1,18) = 23.9$, $p<0.001$). Tests of simple main effects revealed that during acquisition, subjects performed better with the linear text than with hypertext ($F(1,18) = 19.9$, $p<0.001$). However, at retention subjects performed better with hypertext than with linear text ($F(1,18) = 6.3$, $p<0.02$).

Figure 8.1

Mean number of factual questions correctly answered - Experiment 10

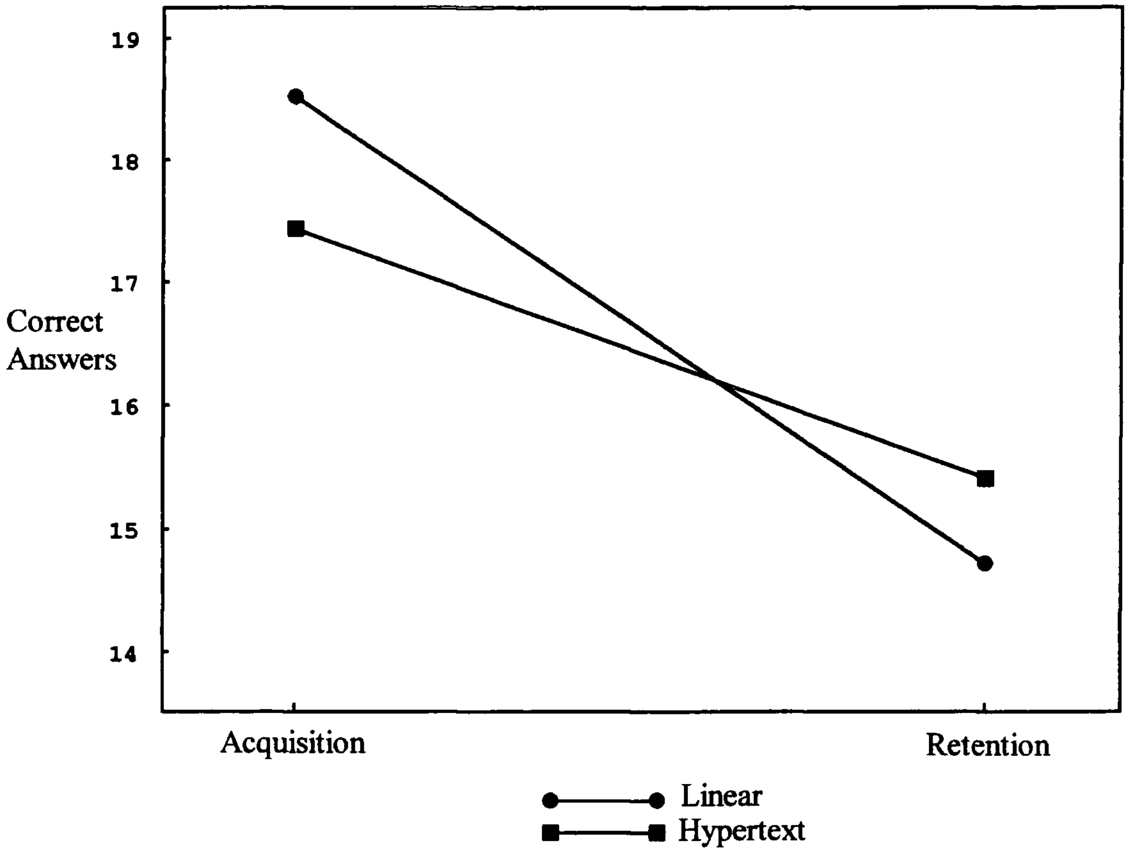


Main ideas questions

Figure 8.2 presents the mean number of main idea questions correctly answered during the acquisition and retention phases the maximum achievable score was 20. A 2 x 2 ANOVA revealed a significant main effect of test phase only ($F(1,18) = 91.8$, $p<0.001$). The main effect of test phase arose because subjects answered more questions correctly during acquisition than during retention. There was no effect of text type ($F(1,18) = 2.3$, $p < 1$).

However there was also a significant interaction between text organisation and test phase ($F(1,18) = 12.2$, $p<0.001$). Tests of simple main effects revealed that during acquisition, subjects performed better with the linear text than with hypertext ($F(1,18) = 4.5$, $p<0.05$). However, at retention subjects performed better with hypertext than with linear text ($F(1,18) = 5.7$, $p<0.03$).

Figure 8.2
Mean number of main ideas correctly answered - Experiment 10



Questionnaire data

After reading both texts subjects completed the disorientation questionnaire used in experiments 1 and 2. The top row of Table 8.3 presents the mean ratings for the disorientation scale. The greater the rating the higher perceived disorientation. The bottom row of Table 8.2 presents the mean ratings for the perceptions of leaning scale, the higher the rating the greater the perceived learning difficulties.

Table 8.3

Mean scores for the disorientation and learning questionnaire - Experiment 10

	Linear	Hypertext
Disorientation Scale	23.1	39.2
Perceptions of learning scale	20.8	35.0

A repeated measures ANOVA for the disorientation scales revealed a significant effect text organisation ($F(1,18) = 58.3$, $p < 0.001$). Subjects rated themselves as having experienced more navigational problems when using hypertext than when using linear text. There was no effect of text type ($F(1,18) = 0.0$, $p < 1$).

A repeated measures ANOVA for the perceptions of learning scale revealed a significant effect of text organisation ($F(1,18) = 47.2$, $p < 0.01$). Subjects rated themselves as having experienced more learning difficulties when using hypertext than linear text. There was no effect of text type ($F(1,18) = 0.30$, $p < 1$).

In addition to the questionnaire data, subjects were asked to indicate which text organisation they thought required the greater mental effort to understand, and which of the two texts they preferred. Table 8.4 presents the response frequencies for additional learning questions.

Table 8.4

Response frequencies for additional learning questions - Experiment 10

	Hypertext	linear text
Text required most mental effort	18	2
Preferred text	3	17

A chi-square analysis revealed that subjects thought the hypertext document required greater mental effort to understand (df = 1, $X^2 = 12.8$, $p < 0.01$). A chi-square analysis also revealed that subjects preferred the linear text to the hypertext (df = 1, $X^2 = 9.8$, $p < 0.01$)

Subjects were also asked to state which text they found to be the most difficult in terms of the subject matter. A chi-square analysis revealed no significant difference (df = 1, $X^2 = 0.4, p < 1$)

DISCUSSION

The results show that in terms of navigation subjects took longer to locate information and experienced greater difficulty following a direct route through the document when using hypertext than when using linear text. As regards learning, the results show that during acquisition the linear text produced better learning for both facts and main ideas than hypertext. However, hypertext led to better long term retention than the linear text. The results of the questionnaire data show that subjects experienced more navigational problems and greater learning difficulties when using hypertext than when using linear text. The results also show that subjects preferred the linear text, and rated the hypertext as requiring greater mental effort to understand.

The results for the navigation measures confirmed the previous findings of the studies reported in this thesis. That is, subjects experience significantly more navigational problems in hypertext than in traditional linear text. Undoubtedly, this is because of the multiplicity of choice offered by hypertext. As the number of links increases between nodes, so does the possibility that users will become lost or disorientated. The results for the learning measures also confirm and strengthen the findings of previous studies. On both learning measures (facts and ideas) performance during acquisition was better with the linear text than with hypertext. However, at retention the reverse was true.

The frequency with which navigational problems are reported in association with hypertext has led some commentators to suggest that hypertext may be an inappropriate medium for learning. As mentioned in chapter 3, learning is believed to suffer in hypertext because the learner will have fewer mental resources directed towards the task of learning because they will have to simultaneously focus on monitoring and controlling their navigation through the document as well as attending to the task of learning. However, the results of this and previous studies presented in this thesis suggest that although learners may experience navigational problems, they can still learn quite effectively from hypertext. Indeed subjects in this study demonstrated better long term retention with hypertext than with linear text.

However, analysis of the questionnaire data reveal that subjects rated themselves as having experienced greater disorientation and greater learning difficulties in hypertext than in linear text. Moreover, subjects indicated that they preferred the linear presentation to the hypertext presentation, and indicated that they thought the hypertext document required greater mental effort to understand. These findings support those of Gordon et al (1988).

Although subjects preferred the linear presentation, they actually performed better with hypertext at least on the learning measures. These findings support those of (Carrier, 1984; Tobias, 1972; Peterson and Janicki, 1972) who found that performance under a preferred mode led to lower achievement than participation in a less preferred mode. For example, Tobias found that college students who were allowed to choose between overt and covert response styles in a programmed instruction lesson did not benefit when assigned to the version of their choice. Similarly, Peterson and Janicki (1979) asked sixth grade students to indicate their preference for small group or large group instruction. When students were assigned to either their preferred or non-preferred condition, Peterson and Janicki found that their performance was worse in the condition of their choice. Snow and Peterson (1980) explain this phenomena by arguing that students often prefer methods of instruction that they think will require less work, concentration, and time. However, if the students do not need to work as hard under preferred modes, they may in fact learn less. The fact that subjects in this study preferred the linear text, presumably because they found it easier and faster to use, does not guarantee that, in the long term, they will learn more from this type of text than from a hypertext document, where they may have to invest more time and effort in the learning process.

SUMMARY

The navigational problems experienced in hypertext do not preclude the use of hypertext for learning. The results show that hypertext can lead to better long term learning than linear text. However, subjects expressed a preference for linear text, and stated that they believed hypertext required greater mental effort to understand. Indeed, although hypertext can lead to better long term learning, the navigational difficulties experienced during reading may deter all but the most highly motivated reader. One way to reduce the burden of navigation is to give learners some form of navigational aid. This issue is further examined in chapter 9.

9

Tools to support learning

INTRODUCTION

One possible way to help learners manage the freedom they are given is to provide them with some kind of navigation/learning aid, such as a spatial map or contents list. Previous research has found that the provision of a spatial map and a contents list can help to eliminate some of the navigational problems often experienced by hypertext users (Monk, Walsh, and Dix, 1988; Simpson and McKnight, 1990; Gupta and Gramopadhye, 1995). Indeed, the findings of experiment six presented in chapter 5, showed that the navigation performance of subjects improved when they were given access to textual contents lists, and was even better when they were given localised spatial maps of the hypertext. Although maps have been shown to facilitate navigation, it does not necessarily follow that they will also facilitate learning. Navigational aids such as contents lists and spatial maps in particular, appear to foster efficient navigation, but efficient navigation may not be a prerequisite of efficient or effective learning. As Dee-Lucas (1996) points out, the better, more accurate navigation that arises from the use of a map, may also result in less breadth of learning by reducing the range of information read. That is, readers will be more likely to travel directly to target information and so neglect to view related but non-target nodes. Moreover, the information presented by these aids, only depicts structural relationships, they say little about the conceptual structure of the text, and so are in themselves unlikely to foster conceptual understanding.

Indeed, research studies conducted by Wenger and Payne (1994) and Stanton et al (1992) have failed to show any benefits to be derived from using maps for learning. However, our ability to draw precise conclusions from these studies is limited because of a number of methodological problems. Therefore, the aim of experiment 11 is to provide more empirical data as to the effectiveness of these aids in supporting learning. The study examines the performance of subjects on both measures of both navigation and learning. One group of subjects had access to a textual contents list, a second group had access to localised spatial maps of the hypertext, a final group of subjects had no navigational aid. In terms of navigation it is predicted that subjects in the map condition will demonstrate superior navigation to subjects in the contents list condition, who in turn will perform better than subjects in the no aid condition. However, for measures of learning it is predicted that these navigational aids will not produce superior learning.

As pointed out above, one of the limitations of navigational aids, such as a map, is that they merely represent the structural layout of the document. That is, they only show which nodes are related to each other. They say nothing about this relationship or why it exists. As such, they are unlikely to foster conceptual understanding. What seems to be needed, therefore, to improve learning from hypertext is an aid that facilitates conceptual understanding of the text, not one that simply facilitates the location of information. We therefore constructed such an aid, which we called a conceptual map. In contrast to a spatial map which simply depicts the structural properties of a document, a conceptual map identifies the key concepts in the text and specifies the relations between them. Experiment 12 examines the effectiveness of a conceptual map compared to a spatial map in supporting learning in hypertext. We predicted that subjects using the spatial map would show superior navigation, while those using the conceptual map would show superior learning.

In order to obtain a true measure of learning, we tested subjects not only immediately after acquisition but a week later as well. We also distinguished between facts and ideas presented in the text. We hypothesised that in the short term, a spatial map might facilitate the learning of facts because a spatial map should enable subjects to construct a representation of the text that encodes the location of factual information. However, such a superficial structural representation should be short lived and so not available a week after learning. We also hypothesised that a conceptual map should facilitate long term learning of both facts and ideas. This is because a conceptual map should enable subjects to construct a representation of the situation described by the text. Such a representation encodes the relationships between concepts in the text and concepts retrieved from the learner's general knowledge store. An integrated representation of this kind should be more durable than a superficial structural representation (see, e.g. Johnson-Laird, 1983; van Dijk and Kintsch, 1983).

We also included a group of subjects who had no aid and who simply read the basic hypertext. We expected such subjects to navigate poorly, as has been found in previous research. However, research on learning in basic hypertext has produced mixed results. Some researchers emphasise the detrimental effects of having too much choice and not enough guidance (Hammond, 1989); others emphasise the potential learning gains associated with discovery learning (Mayes, Kibby and Anderson, 1990). It is possible that both views are correct, with the result that learning may be better with basic hypertext than with a more structured text, but it may also take more time to achieve these learning gains. If this possibility is correct, we might expect learning without an aid to be superior to learning with a spatial map but less good than with a conceptual map.

EXPERIMENT 11

METHOD

Subjects

Thirty six student volunteers from Durham University served as subjects. Each subject was tested individually. At the start of the experiment subjects were unfamiliar with the ideas and concepts discussed in the text.

Materials

The non-linear version of the hypertext document used for experiment 1 (chapter 4) was used in this study (See Appendix A). One group of subjects used the basic hypertext. A second group were given access to a contents list (see page 97, Chapter 6 for an example), a third group were given access to a spatial map (see page 97, Chapter 6 for an example). In the map condition subjects were provided with localised spatial maps of the document. In the contents list condition subjects were provided with a scrollable contents list of all 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.

Design

The experiment used a between subjects design. The independent variables were navigational aid (map, contents list, raw hypertext). The dependent variables consisted of measures of both navigation and learning. The navigation measures were: the mean time to locate the target nodes, and the number of additional nodes opened. (The shortest route to each target node was determined. This figure was subtracted from the actual number of nodes opened by subjects to give an additional node score). The learning measures were: the number of questions correctly answered, and the mean number of node titles correctly recalled.

Each subject was randomly assigned to one of the three experimental conditions (map, contents list, basic hypertext). Subjects were required to read through and understand the experimental text. Subjects then completed a search task and answered twenty questions about the documents content. Finally subjects were instructed to free recall as many node titles as they could in two minutes.

Procedure

Before the experiment began subjects were asked to answer twenty questions about the information contained in the experimental text. These questions were scored immediately by the experimenter. Only those subjects who scored less than 20% of the questions correct were used as subjects. This measure was taken in order to minimise the effects of prior knowledge.

After initial tuition on how to use the computerised document, subjects were instructed to read through, and to try and understand the experimental text. Subjects were instructed to use the navigational aid whenever they felt it was necessary. When subjects felt they had understood the text they were instructed to navigate through the hypertext to locate ten target nodes, taking the most direct route possible, using the navigational tools as necessary. The time spent reading, the number of additional nodes opened, and the time taken to locate each target node were recorded. The presentation order for the ten target nodes was randomised for each subject. Subjects were then required to answer twenty factual questions about the text. For example, *What is means-ends-analysis?* Subjects answered in writing, without time restrictions. The number of correct answers was recorded for each subject. Subjects were then allowed two minutes in which to recall as many node titles as possible. The questions used in this study can be found in Appendix E.

RESULTS

Reading

Time spent reading

The time spent on reading in minutes by subjects in each condition was:- spatial map 38.8; contents list 39.25; and hypertext 37.25. A one way ANOVA revealed that there were no significant differences between the three groups ($F(2,33) = 0.585, p < 0.563$).

Navigation Measures

Time taken

The mean number of seconds taken to locate the target nodes was :- spatial map: 77.3 ; contents list: 93.4; and hypertext: 113.5. A one way ANOVA revealed a significant effect of aid ($F(2,33) = 23.8$, $p < 0.01$). Tukey HSD tests indicated significant differences between each condition, (spatial map vs. hypertext: $Q(3, 33) = 9.74$, $p < 0.01$; spatial map vs. contents list: $Q(3, 33) = 4.32, p < 0.05$; contents list vs. hypertext: $Q(3, 33) = 5.43, p < 0.01$).

Additional cards

The mean number of additional nodes opened was:- spatial map: 1.2; contents list: 4.2; and hypertext: 6.4. A one way ANOVA revealed a significant main effect of aid ($F(2,33) = 107.43, p < 0.01$). Tukey HSD tests indicated significant differences between all conditions, (spatial map vs. hypertext: $Q(3, 33) = 20.7$, $p < 0.01$; spatial map vs. contents list: $Q(3, 33) = 11.8, p < 0.01$; contents list vs. hypertext: $Q(3, 33) = 8.9$, $p < 0.01$).

Learning Measures

Questions Correctly Answered

The number of questions correctly answered was recorded for each subject. The mean number of questions correctly answered was :- spatial map: 15.3; contents list: 14.7; hypertext: 16.3. A one way ANOVA revealed no significant differences between the three groups.

Node Titles Recalled

The number of node titles correctly recalled was recorded for each subject. The mean number of node titles correctly recalled was :- spatial map: 25.9; contents list: 23.8; hypertext: 17.9. A one way ANOVA revealed a significant effect of aid ($F(2,33) = 6.8$, $p < 0.01$). Tukey HSD tests indicated significant differences between the hypertext condition and the other two conditions only (spatial map vs. hypertext: $Q(3, 33) = 5.1$, $p < 0.01$; contents list vs. hypertext: $Q(3, 33) = 3.74$, $p < 0.05$; spatial map vs. contents list: $Q(3, 33)$ $p < 1$).

DISCUSSION

The results of experiment 11 show that although navigational aids such as maps and contents lists can facilitate navigation, they do not seem to benefit learning. These findings support those of Wenger and Payne (1994) and Stanton et al (1992) who also found that learning was not improved by the provision of spatial maps.

In terms of navigation, the performance of subjects in the map condition was superior to that of subjects in the hypertext condition, while the performance of subjects in the contents list condition fell between these two extremes. These results replicate the previous findings of experiment 6 (chapter 5) and work conducted by Monk, Walsh and Dix, 1988; Simpson and McKnight 1990).

The one learning measure that was facilitated by the navigational aids was the number of node titles that were correctly recalled. This is likely to have occurred because subjects in the map and contents list condition will have received a double exposure to the node titles, because they will have seen them in both the text and the navigational aid.

One limitation of these results is that they only tested short term learning, the next study examines short term and long term retention of information learned in hypertext with the assistance of either a spatial map or a conceptual map which depicts the conceptual relationships that lie within the text, rather than the structural properties of the document.

EXPERIMENT 12

METHOD

Subjects

Thirty two student volunteers from Durham University served as subjects. All subjects had equivalent computer experience, and were unfamiliar with the subject matter of the text. Subjects were tested individually.

Materials

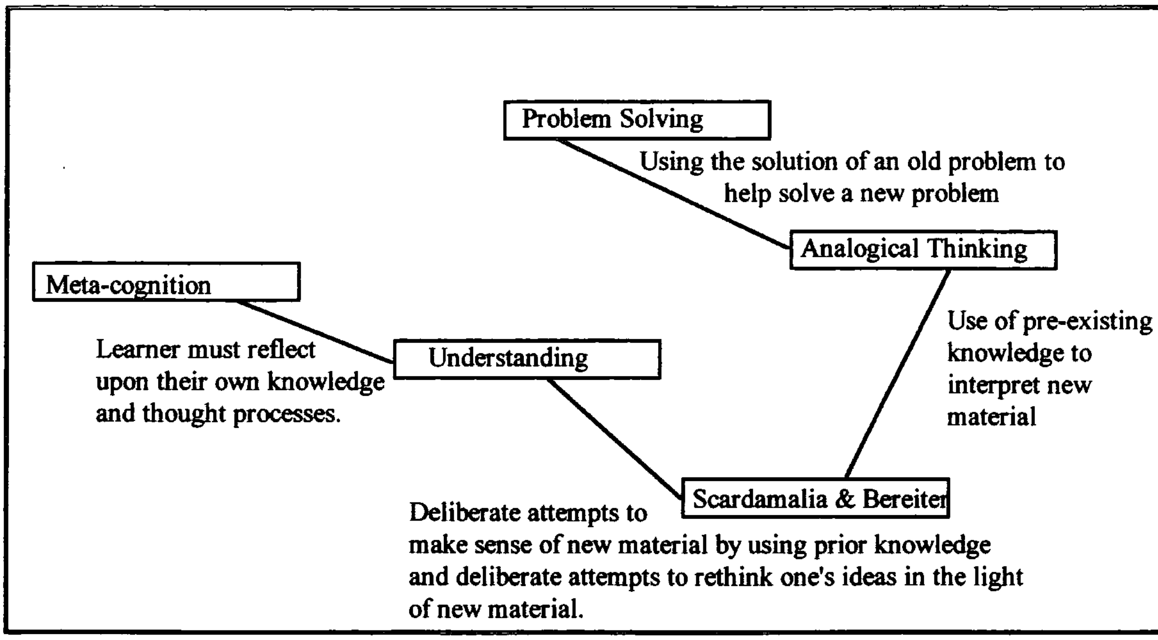
Three hypertext documents were used (spatial map, conceptual map, basic hypertext). In the spatial map condition subjects were provided with localised spatial maps that displayed the area of the hypertext subjects were in at any one time. (See page 97, chapter 6 for an example). The conceptual map condition consisted of a map of the concepts expressed in the text and descriptions of the links between them. (See Figure 9.1.). In the basic hypertext condition, no navigational aid was provided. The same text was used as in experiment 11.

Design

The investigation of the effects of aid on navigation used a between subjects single factor design. The independent variables were navigational aid, (spatial map, conceptual map, and basic hypertext); the dependent variables were the time spent reading, the mean time to locate the target nodes, and the number of additional nodes opened. (The shortest route to each target node was determined. This figure was subtracted from the actual number of nodes opened by subjects to give an additional node score). The investigation of the effects of aid on learning used a between and within subjects mixed factorial design. The independent variables were navigational aid (spatial map, conceptual map, basic hypertext), and test phase (acquisition and retention). The dependent variables were, the number of factual and main ideas questions correctly answered.

Figure 9.1

An Example of a section of a localised conceptual map



Procedure

In order to minimise the effects of prior knowledge subjects answered twenty questions about the content of the text. Those subjects who had less than 20% of the correct answers were used as subjects. After initial tuition on how to use the computerised document, subjects were instructed to read, and to try and understand, the experimental text, using the navigational aid as necessary. When subjects felt they had understood the text they were instructed to navigate through the hypertext to locate ten target nodes, taking the most direct route possible, using the navigational tools as necessary. The number of additional nodes opened, and the time taken to locate each target node were recorded. The presentation order for the ten target nodes was randomised for each subject.

Subjects then answered forty questions about the text. Half of the questions tapped memory for factual information. For example, "*Who developed the pragmatic model of analogical thinking?*" and "*Name one of the four component processes of analogical thinking.*" The remaining questions required a deeper understanding of the text. For example, "*Why is understanding the most difficult form of explicit learning?*" and "*Explain the theory of Transfer Appropriate Processing*". The answers to these questions were scored as correct if they could be considered to be a paraphrase of the correct answer. One week later subjects returned to the laboratory to complete a retention test consisting of a further forty questions. Questions were counterbalanced across the test phases. Subjects were informed that a second visit to the laboratory was necessary for them to complete a reading speed test. The true purpose of the visit was concealed in order to minimise the possibility that they might try to rehearse the material during retention. Subjects were thoroughly debriefed at the end of the experiment. A full list of the target nodes used for the search task and the learning questions used in this study can be found in Appendices D and E respectively.

RESULTS

Reading

Time spent reading

The time spent on reading in minutes by subjects in each condition was:- spatial map 41.0; conceptual map 38.8; and hypertext 39.2. A one way ANOVA revealed that there were no significant differences between the three groups ($F(2,33) = 0.605, p < 0.554$).

Navigation:

Time taken:

The mean number of seconds taken to locate the target nodes was :- spatial map: 81.8; conceptual map: 102.2; and hypertext: 124.3. A one way ANOVA revealed a significant effect of aid ($F(2,27) = 15.5$, $p < 0.01$). Tukey HSD tests indicated significant differences between each condition, (spatial map vs. hypertext: $Q(3, 27) = 7.9, p < 0.01$; spatial map vs. conceptual map: $Q(3, 27) = 3.8, p < 0.05$; conceptual map vs. hypertext: $Q(3, 27) = 4.1, p < 0.05$).

Additional Nodes

The mean number of additional nodes opened was:- spatial map: 1.9; conceptual map: 3.8; and hypertext: 8.8. A one way ANOVA revealed a significant main effect of aid ($F(2,27) = 56.8$, $p < 0.01$). Tukey HSD tests indicated significant differences between all conditions, (spatial map vs. hypertext: $Q(3, 27) = 14.5$, $p < 0.01$; spatial map vs. conceptual map: $Q(3, 27) = 3.8$, $p < 0.05$; conceptual map vs. hypertext: $Q(3, 27) = 10.7, p < 0.01$).

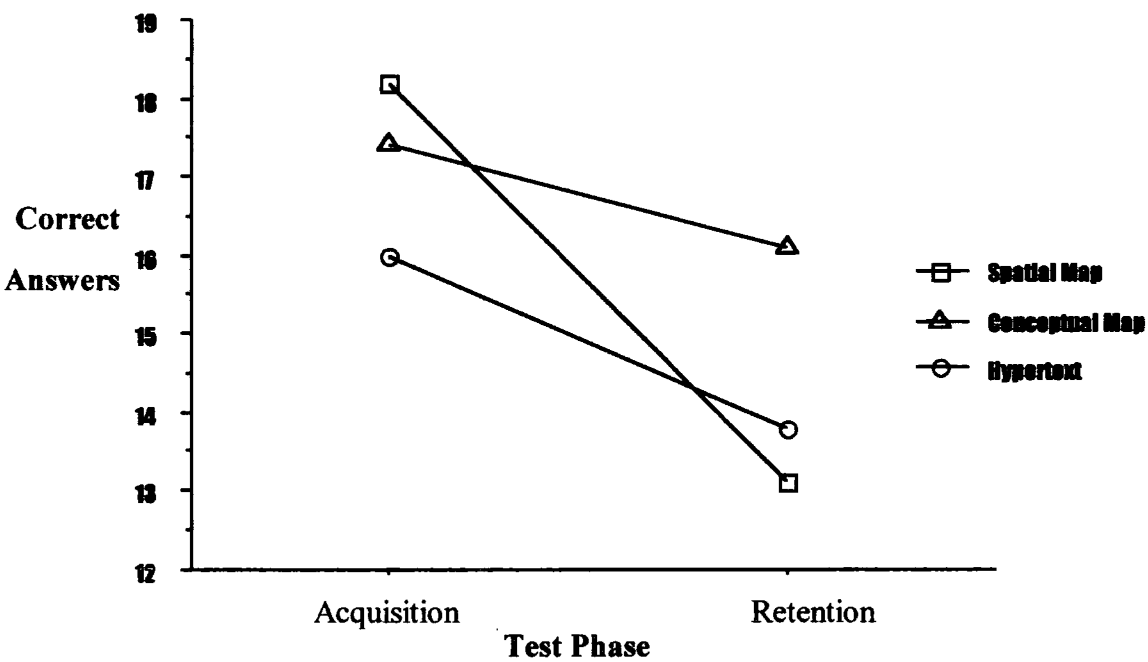
Learning

Factual Questions:

Figure 9.2 presents the mean number of factual questions correctly answered during the acquisition and retention phases.

A 3 x 2 ANOVA revealed two significant main effects: aid ($F(2,27) = 5.3$, $p < 0.01$), and test phase ($F(1,27) = 99.9$, $p < 0.01$), and a significant interaction between them ($F(2,27) = 15.9$, $p < 0.01$). Tests of simple main effects revealed that performance at acquisition was better than at retention for all three conditions (hypertext: $F(1,27) = 19.6$, $p < 0.01$; spatial map: $F(1,27) = 105.5$, $p < 0.01$; conceptual map: $F(1,27) = 6.9$, $p < 0.01$). There was also an effect of aid at both the acquisition phase: ($F(2,35) = 5.5$, $p < 0.01$) and the retention phase: ($F(2,35) = 10.9$, $p < 0.01$).

Figure 9.2
Mean number of factual questions correctly answered as a function of navigational aid and test phase

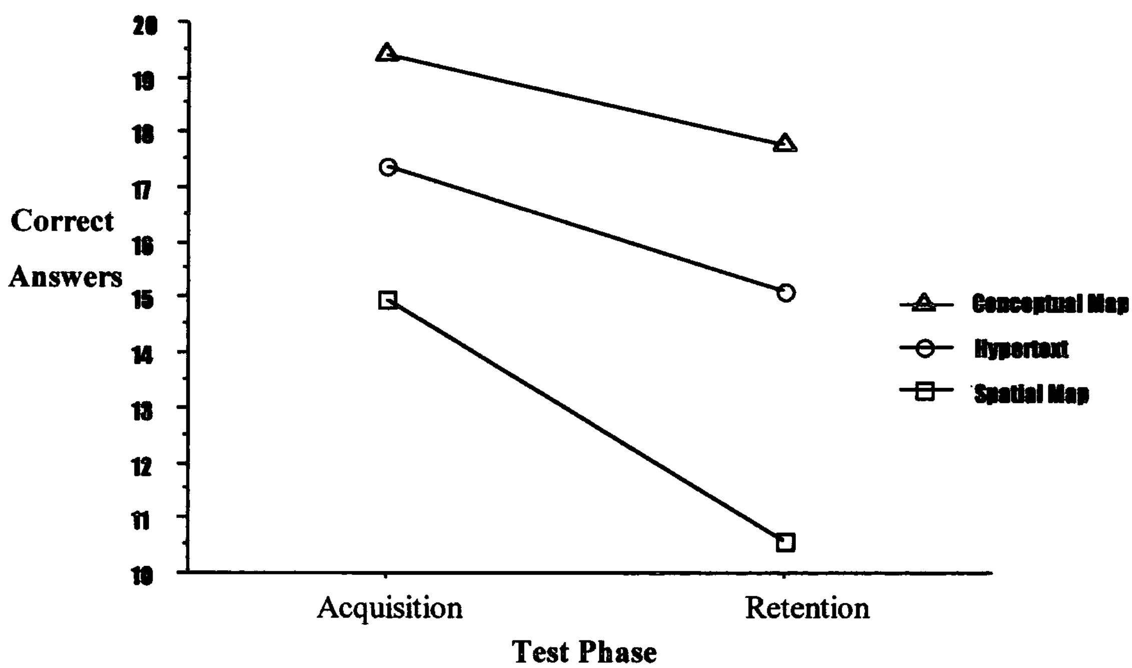


Pair-wise comparisons using the Newman Keuls test examined the effect of aid at each test phase. At the acquisition phase subjects in the spatial and conceptual map conditions answered more questions correctly than subjects in the hypertext condition (spatial map vs. hypertext: ($Q(3,27) = 5.5$, $p < 0.01$; conceptual map vs. hypertext: $Q(2,27) = 3.5$, $p < 0.05$). Subjects in the spatial map and conceptual map conditions did not differ from each other ($Q = 1.9$, *ns*). In the retention phase subjects in the conceptual map condition answered more questions correctly than subjects in the other two conditions (conceptual map vs. spatial map: ($Q(3,27) = 7.4$, $p < 0.01$; conceptual map vs. hypertext: ($Q(2,27) = 5.7$, $p < 0.01$). There was no difference in the performance of subjects in the hypertext and spatial map conditions ($Q = 1.7$, *ns*).

Main Ideas Questions:

Figure 9.3 presents the mean number of main ideas questions correctly answered during the acquisition and retention phases.

Figure 9.3
Mean number of main ideas questions correctly answered as a function of navigational aid and test phase



A 3 x 2 ANOVA revealed two significant main effects: aid ($F(2,27) = 16.9$, $p < 0.01$), and test phase ($F(1,27) = 76.6$, $p < 0.01$), and a significant interaction between them ($F(2,27) = 7.1$, $p < 0.01$). Tests of simple main effects revealed that performance was better at acquisition than at retention for all three conditions (hypertext: $F(1,27) = 17.7$, $p < 0.01$; spatial map: $F(1,27) = 64.6$, $p < 0.01$; conceptual map: $F(1,27) = 8.5$, $p < 0.01$). There was also an effect of aid at both the acquisition phase: $F(2,35) = 8.4$, $p < 0.01$; and retention phase: $F(2,35) = 22.9$, $p < 0.01$. Pair-wise comparisons using the

Newman Keuls test revealed that at the acquisition phase subjects in the conceptual map and hypertext conditions answered more questions correctly than subjects in the spatial map condition (conceptual map vs. spatial map: $Q(3,27) = 6.2$, $p < 0.01$; hypertext vs. spatial map: $Q(2,27) = 3.4$, $p < 0.05$). The difference between the conceptual map and hypertext condition failed to reach significance ($Q = 2.8$, *ns*). In the retention phase there were differences between all three groups. (conceptual map vs. spatial map: $Q(3,27) = 10.2$, $p < 0.01$; conceptual map vs. hypertext: $Q(2,27) = 3.8$, $p < 0.05$; hypertext vs. spatial map: $Q(2,27) = 6.4$, $p < 0.01$). Subjects in the conceptual map condition gave more correct answers than subjects in the hypertext condition, who in turn gave more correct answers than subjects in the spatial map condition.

DISCUSSION

In the main, these results support the predictions. Navigation was best with a spatial map, next best with a conceptual map and poorest with hypertext. The spatial map and basic hypertext results for navigation are consistent with previous findings (experiments 6 and 11). The observation that a conceptual map also facilitates navigation relative to basic hypertext is most likely due to the fact that spatial information and conceptual information overlap. The observation that facilitation resulting from a conceptual map was not as great as from a spatial map may be because the conceptual map specifies the nature of the links between nodes and this relational information may interfere with the spatial information that is also encoded in the links.

The predictions about learning were also confirmed, particularly regarding the comparison between a spatial map and a conceptual map. With the factual questions, a spatial map and a conceptual map produced comparable learning immediately after acquisition, but after a week's delay, spatial map subjects showed poor retention compared to conceptual map subjects. These results support the idea that a spatial map helps subjects construct a superficial structural representation of the text that is useful in the short term for retrieving factual information but that decays very quickly.

With the main ideas questions, the conceptual map subjects outperformed the spatial map subjects at both retention intervals. This result also supports the idea that a spatial map leads to the construction of a superficial representation of the text. It also supports the idea that a conceptual map facilitates the construction of a situation model (van Dijk and Kintsch, 1983) or a mental model (Johnson-Laird, 1983) of the information in the text. A situation model encodes the relationships between concepts, including concepts already stored in the learner's long term knowledge store, and such an integrated representation supports the long term retention of facts and ideas.

The predictions concerning the basic hypertext were confirmed with the main ideas questions but not with the factual questions. With factual questions, performance was poorer than with either aid on immediate testing, and poorer than with the conceptual map after a delay. With main ideas questions, performance at both test phases was better than with a spatial map but poorer than with a conceptual map. These results suggest that pure discovery learning with hypertext favours conceptual understanding at the expense of the acquisition of new facts, although even conceptual learning is not as good as with a conceptual map. This suggestion is consistent with the idea that pure discovery learning in hypertext is time-consuming, and further indicates that facts are more likely to suffer than ideas.

SUMMARY

Taken together, these results strongly favour the use of a spatial map in navigation and information retrieval tasks, and a conceptual map in learning tasks. Basic hypertext also encourages learning, but the time spent navigating through the document may delay its beneficial effects, particularly when learning facts, and this may deter all but the most highly motivated learner. By contrast, the constraints imposed on navigation by a conceptual map not only reduce the time spent exploring the document but also significantly enhance learning.

10

Summary and conclusions

INTRODUCTION

The primary focus of this thesis was to investigate the effects of non-linear hypertext on both navigation and learning. This final chapter presents a summary of the main experimental findings.

Navigation Results

Disorientation in hypertext

The results of experiments 1-4 suggest that disorientation is a problem for hypertext users. Typically, hypertext users encounter problems in deciding if the information they require is available, where to look for it, and how to get there. The cause of the problem seems to be the multiplicity of choice offered by non-linear texts. Users must carry out several tasks at once, such as planning and executing routes through the document, as well as, reading and understanding the text content. The simultaneous execution of these tasks can place heavy demands on the user's working memory resources which can cause a decline in performance resulting in disorientation.

The results of experiments 1- 4 also suggest that linking structures can have an effect on navigation performance. In terms of information retrieval non-linear texts are supposed to offer two main advantages. First, this type of structure is intended to make information more accessible to the reader. For example, in a hierarchically structured hypertext, moving from the top of the hierarchy to a node at the bottom may require the user to traverse several links, whereas the identical trip in a network structure of the same document may only require a single link. Second, the structure allows the user non-linear access to the information. The reader may choose to follow a variety of paths through the document, increasing his/her control over the sequencing of the information.

However, the results of experiments presented in this thesis suggests that users experience quite severe navigational problems with non-linear texts.

Collectively, the results of experiments 1, 2 and 3 suggest 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. Overall, the best performance was demonstrated by subjects who used a traditional linear text. The superior performance of the subjects using the linear text may be accounted for by the familiarity of this text structure. Readers expect texts to conform to particular criteria or types. The linear text will have conformed to the subject's expectations of how the text might be structured, therefore they will have been able to use the document more easily. The difference in performance may also be accounted for by the high degree of control offered by hypertext in terms of the number of alternative links available for subjects to follow.

The difference in performance between subjects using the hierarchical and non-linear texts may also be due to the differing amount of user control offered by the two text organisations. Although the hierarchical document does not constrain the user to a single path through the document, its organisational structure does confine the users' movements and hence their freedom to browse. However, the non-linear structure places few constraints on the user's movements, they have unlimited freedom to explore a richly connected non-linear network of ideas. From the performance of subjects using this document it appears that this freedom has its associated costs. Indeed, the advantages of non-linear texts may be severely limited if users are unable to find their way around unfamiliar and complex information structures without experiencing disorientation. Some researchers feel that such non-linear texts are of limited value, especially to beginners in the subject matter of the text. For example, Brown (1989) argued that complex non-linear hypertext is inappropriate for novice users and suggested that a simple hierarchical structure should be employed with only a few cross-reference links that cut across the hierarchy. Experiment 4 tested out this idea with subjects with and without prior knowledge of the text topic. The results show that the problem of disorientation is particularly heightened for those users unfamiliar with the subject matter of the text, who cannot rely upon their existing prior knowledge to help them structure the text. The problem also seems to be particularly marked when non-linear texts are used. A mixed text, by contrast, considerably eases the disorientation problem as does a hierarchical text, although to a lesser extent. Another way to reduce the navigation load in hypertext is to give the user access to some kind of navigational aid, that works by allowing them to review and preview their progress through hypertext.

Navigation and human spatial processing

Researchers such as Canter, Rivers and Storrs (1985) have argued that there are direct parallels between navigation in real world environments and electronic space. However, research has failed to show the extent to which the psychology of real world navigation maps onto navigation in electronic space.

Spatial knowledge of a new (real world) environment is believed to progress through three levels of representation; landmark knowledge, route knowledge, and survey knowledge. Survey knowledge being the most advanced and elaborate representation which is often referred to as a cognitive map. Studies have shown that successful navigation in the real world is dependent upon the formation of survey knowledge. This has also been found to be the case in hypertext. Studies conducted by Edwards and Hardman (1989) and Simpson and McKnight (1990) have found that those subjects who score highly on measures of survey knowledge (i.e. a cognitive map task) demonstrate more efficient navigation behaviour. The results of experiments 5 and 6 presented in this thesis also showed a relationship between navigation performance and scores on a cognitive map task.

Real world studies have also shown that the method by which people acquire spatial knowledge may influence the type of spatial knowledge they have and the way it is represented. Thorndyke and Hayes-Roth (1982) suggest that people acquire different types of knowledge from different sources. In the first instance, from navigation we acquire route knowledge and from map study we acquire survey knowledge. Thorndyke and Hayes-Roth suggest that while the knowledge acquired through navigation will ultimately lead to the development of an elaborate mental representation or cognitive map, there are two factors that map hamper the development of survey knowledge from direct navigational experience. First, the regularity of the environment under study will affect the speed at which survey knowledge can be derived from navigation alone. Consequently, in complex irregular environments such as hypertext, the development of survey knowledge from navigation may be decelerated. Second, survey knowledge is difficult to acquire and can take some considerable time to develop. These observations are of particular importance for hypertext. First, it is often the case, that in the situations where hypertext is employed, for example, in information retrieval, users need to acquire survey knowledge about their environments very quickly. In other words it is not practical or even possible for them to gain survey knowledge of the environment by extensive navigation experience. Second, hypertext is by nature a very irregular environment, consequently, navigation alone may not be the most efficient way to obtain a well developed cognitive map. Experiment 5 tested these ideas by comparing the performance of subjects who are allowed direct navigational experience (referred to as the browsing group) in hypertext, with a group of subjects who are given a map of the system's structure to learn. The results showed that the development of survey knowledge in hypertext users is enhanced when they are given the opportunity to study a map of the database. Experiment 5 also examined the relationship between spatial knowledge and subject prior knowledge. The results showed that the provision of a map especially for those unfamiliar with the knowledge domain, may accelerate the development of a cognitive map of the hypertextual space which they can use to guide their subsequent navigation through the document. Consequently, map learners were able to navigate through the document more efficiently than browsing subjects. This is probably due to the irregularity of the environment and to the fact that spatial knowledge is harder to acquire from navigation alone (Thorndyke and Hayes-Roth 1982).

Thus there do seem to be some parallels between three aspects of real world navigation and navigation in electronic space. First, successful navigation is dependent upon the development of a cognitive map. Second, the regularity of the environment affects the speed at which spatial knowledge develops. Third, survey knowledge takes longer to acquire through navigational experience alone. Experiment 6 examined the effects of presenting users with an on-line map of the hypertext compared with a text based navigation aid. The results showed that performance in the map condition was superior to that of the contents list condition, which in turn was better than that in the hypertext condition (no navigational aid). In addition, knowledgeable subjects performed better than non-knowledgeable subjects, except in the map condition where their performance was equivalent.

Taken together these results seem to provide strong support for the use of the navigation or spatial metaphor in hypertext and suggest that spatially based navigational aids might be a suitable remedy for the problem of disorientation in hypertext. Moreover, the results of the correlational and regression data presented in experiments 1, 2, and 3 (chapter 4) suggests that there is a relationship between individual differences in spatial ability and navigation performance in hypertext. That is, users with good spatial skills demonstrate superior navigation performance than users with poor spatial skills. Moreover, the relationship exists in knowledgeable as well as non-knowledgeable subjects (experiment 4, chapter 5). However the relationship does not hold for linear texts possible because they are two dimensional, unlike hypertext in which the user can travel in any number of directions. Again this provides support for the use of spatially based aids to navigation.

Synopsis - navigation

In summary, the results of the navigation studies suggest that disorientation is a problem for hypertext users. The problem is especially marked for those users who are unfamiliar with the subjects matter of the text, and for users of complex non-linear hypertexts. One possible way to alleviate the problem of disorientation is to provide some form of navigational aid. The results show that while users benefit from aids such as contents lists, they benefit more from localised spatial maps of the hypertext document. However, it remains to be seen whether these results will generalise to large hypertext documents.

Learning Results

Good navigation versus good learning

Hypertext is believed to foster learning because it provides an open exploratory learning environment offering unusually high levels of learner control. Learners must decide where to go, which links to follow, which nodes to read, and when to stop reading. According to the Cognitive Flexibility Theory (Spiro et al, 1993) environments such as these support learning by allowing learners to revisit the same material at different times, in re-arranged contexts, for different purposes and from different conceptual perspectives. However, these grandiose claims about hypertext's potential value as a learning environment are rarely supported with any solid empirical evidence. Indeed a number of writers suggest that hypertext may hinder the learning process because the navigational problems it creates for learners, and because the modularisation of information into discrete units that can be subject to a variety of different reading orders might disrupt the overall coherence of the text. Indeed, previous work by Gordon et al (1988) has shown that hypertext can disrupt comprehension. However, the results of experiments presented in the proceeding chapters of this thesis suggest that the problems hypertext creates may work for, as well as, against the learner. That is, although hypertext can cause problems during acquisition, it can lead to better overall long term retention. So why might this be the case? Studies presented in Schmidt and Bjork (1992) and Kintsch (1994) suggest that creating difficulties for the learner during acquisition, for example, by disrupting the coherence of a given text, thereby increasing the amount of inferential activity necessary to formulate a situational or mental model of the events described in the text, may enhance long term retention.

Experiments presented in chapters 7 and 8 examined this idea in hypertext. It was hypothesised that the difficulties learners experience with non-linear hypertext might promote them to process the text more actively, leading to better long term retention.

The results showed that although hypertext disrupts performance during acquisition it can lead to better long term retention, especially in the case of subjects who have prior knowledge of the text topic. However, subjects expressed a preference for linear texts. It may be that hypertext acts as a kind of incoherent linear text in which learners must work hard at inferring the relationships between nodes that are linked together when making inter-topic jumps. Moreover, in contrast to linear text where topic shifts are clearly signalled, in order to progress through hypertext readers must continually make high level decisions about what nodes to follow, this may also serve to increase the amount of active processing required from the learner.

However, although hypertext may lead to good long term retention, the results of experiment 10 suggest that learners prefer linear texts and rate hypertext as requiring greater mental effort to understand. It may be that although the active processing induced by hypertext can ultimately improve long term retention, the quite severe navigational problems experienced during learning may deter all but the most diligent reader. In order to overcome his motivational problem some form of support or guidance seems to be necessary.

Hanneman and Haake (1995) have suggested that giving readers access to a spatial map of the hypertext node and links might improve both navigation and learning. However, the results of experiments 11 and 12 suggest that although such maps may improve navigation, they do not improve learning. This finding lends support to the suggestion that good navigation is not always a pre-requisite for good learning. What seems to be needed is some kind of conceptual support which allows learners to see the conceptual links in the hypertext. Thus, rather than simply giving learners a map showing which nodes are related, we need to help learners see *why* nodes are related. One possible way to achieve this is to provide learners with a conceptual map. In contrast to a spatial map which simply depicts the structural properties of a document, a conceptual map identifies the key concepts in he text and specifies the relations between them. Experiment 12 examined the effectiveness of a conceptual map in supporting learning from hypertext compared to a spatial map and a no aid condition. The results show that while a spatial map can support navigation it has no effect on learning. A conceptual map however, enhances long term learning in hypertext. As with the findings on navigation, it remains to be seen whether these results on learning with hypertext will generalise to large scale applications, particularly in classroom settings.

Learning Synopsis

In summary, the results of the learning studies suggest that although the navigational difficulties hypertext creates for its readers can have a negative effect on learning during acquisition. Hypertext can lead to good long term retention, especially with learners who have some prior knowledge of the text topic. It may be that the difficulties hypertext creates stimulate the learner to process the text more actively thereby enhancing learning.

Conclusion

The results of experiments 1 - 4 suggest that disorientation is a problem for hypertext users, especially when non-linear texts are used. Non-linear hypertext places few constraints on users' movements, giving the subjects almost unlimited freedom to explore the network. Unfortunately this freedom has its costs. Users seem to be unable to manage the high level of control offered by this text structure and run into quite serious navigational problems. Moreover, the navigational problems experienced in hypertext seem to be particularly marked for those users who are unfamiliar with the subject matter of the text.

The results of studies 4, 5 and 6 suggest that the problem of disorientation can be reduced by one of two ways. Text or linking structures can be used that minimise the possibility of users getting lost such as the mixed text structure studied in experiment 4. Although this text organisation allowed the subjects to jump across into new sections of the document, its basic hierarchical framework served to constrain the subjects movements preventing them from getting lost. Second, by providing the use with an on-line navigational device, such as a spatial map which allows subjects to review and preview their progress through the text. Both of these methods seem to be helpful to subjects with and without prior knowledge of the text topic.

However, although spatial maps seem to facilitate navigation they do not facilitate learning. Indeed it seems that the efficient navigation that results from the use of a map can prevent users from examining related but non-target information thereby reducing the breadth of learning. Moreover the information presented by such aids merely depicts structural properties. That is, they tell us what nodes are related, they say nothing about this relationship or why it exists. In order to facilitate learning some form of conceptual support is needed such as a conceptual map. Therefore, navigation and learning should be considered separately. Tools that facilitate navigation do not necessarily facilitate learning.

However, the results of experiments 7 - 12 suggest that the problems associated with using non-linear texts do not preclude the use of hypertext for learning. In fact, it may be that the difficulties hypertext creates stimulates the learner to process the text more actively thus enhancing long term retention. Indeed, the results show a clear dissociation between navigation and learning. That is, good navigation does not seem to be a prerequisite for good learning. Unfortunately, however, subjects seem to prefer linear presentation to hypertext even though they demonstrated better long term retention with hypertext.

In conclusion, the results demonstrate a clear dissociation between navigation and learning in hypertext. Although non-linear texts create navigational problems for learners they can facilitate long term retention because learners have to process these texts more actively.

REFERENCES

Allinson, L. & Hammond, N.V. (1989). A learning support environment: the Hitch-Hiker's Guide. In R. McAleese (Eds.), *Hypertext: Theory into Practice* Oxford: Intellect.

Battig, W.F. (1979). The flexibility of human memory. In L.S. Cermak & F.I.M. Craik (Eds.), *Levels of Processing in Human Memory* Hillsdale, N.J.: Erlbaum.

Batra, S., Bishu, R.R. & Donohue, B. (1993). Effects of hypertext topology on navigation performance. *Advances in Human Factors and Ergonomics, 19,* 175-180.

Becker, D.A. & Dwyer, M.M. (1994). Using hypermedia to provide learner control. *Journal of Educational Multimedia and Hypermedia, 3,* 155-172.

Black, A., Wright, P., Black, D. & Norman, K. (1992). Using dictionary inforamtion: some factors influencing whether readers will check the meanings of unknown words in a text. *Hypermedia, 4* 145-169.

Blaut, J.M. & Stea, D. (1974). Mapping at the age of three. *Journal of Geography, 73,* 5-9.

Britton, B.K. & Gulgoz, S. (1991). Using Kintsch's model to improve instructional text: effects of inference calls on recall and cognitive structures. *Journal of Educational Psychology, 83,* 329-345.

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

Caldwell, R.M. (1980). Guidelines for developing basic skills in instruction materials for use with microcomputer technology. *Educational Technology, 20,* 7-12.

Campagnoni, F.R. & Ehrlich, K. (1989). Information retrieval using a hypertext based help system. *ACM Transactions on Information Systems, 7,* 271-291.

Canter, D., Rivers, R. & Storrs, G. (1985). Characterizing user navigation through complex data structures. *Behaviour and Information Technology., 4,* 93-102.

Carmel, E., Crawford, S. & Chen, H. (1992). Browsing in hypertext: a cognitive study. *IEEE Transactions on Systems, Man, and Cybernetics., 22,* 865-884.

Carrier, C. (1984). Do learners make good choices? *Instructor Innovator, 29,* 15-17.

Charney, D. (1994). The impact of hypertext on processes of reading and writing. In S.J. Hilligoss & C.L. Selfe (Eds.), *Literacy and Computers* New York: Modern Language Association.

Collier, G. (1987). Thoth II: hypertext with explicit semantics. In *Proceedings of Hypertext'87,* (pp. 269-289). University of North Carolina: Chapel Hill.

Conklin, J. (1987). Hypertext: an introduction and survey. *Computer,* 17-41.

Dee-Lucas, D. & Larkin, J.H. (1995). Learning from electronic texts: effects of interactive overviews for information access. *Cognition and Instruction, 13,* 431-468.

Dillon, A. (1991). Readers' models of text structures: the case of academic articles. *International Journal of Man-Machine Studies, 35,* 913-925.

Dillon, A. (1994). *Designing usable electronic text.* London: Taylor & Francis.

Dillon, A., McKnight, C. & Richardson, J. (1990). Navigation in hypertext: a critical review of the concept. In D. Diaper (Ed.), *Human-Computer Interaction - Interact '90*

Dillon, A., McKnight, C. & Richardson, J. (1993). Space - the final chapter *or* why physical representations are not semantic intentions. In C. McKnight, A. Dillon & J. Richardson (Eds.), *Hypertext: a psychological perspective* (pp. 169-191). London: Ellis Horwood.

Duchastel, P.C. (1989). Examining cognitive processing in hypermedia usage. *Hypermedia, 2,* 221-233.

Edwards , D. & Hardman, L. (1989). "Lost in hyperspace": cognitive mapping and navigation in a hypertext environment. In R. McAleese (Eds.), *Hypertext: Theory into Practice* (pp. 90-105). Oxford: Intellect.

Elm, W. & Woods, D. (1985). Getting lost: a case study in interface design. In *Proceedings of the Human Factors Society 29th Annual Meeting,* (pp. 927-931).

Fincher-Kiefer, R., Post, T.A., Greene, T.R. & Voss, J.F. (1988). On the role of prior knowledge and task demands in the processing of text. *Journal of Memory and Language, 27,* 416-428.

Fisher, M.D., Blackwell, L.R., Garcia, A.B. & Greene, J.C. (1975). Effects of student control and choice on engagement in a CAI arithmetic task in a low-income school. *Journal of Educational Psychology, 67,* 776-783.

Foltz, P.W. (1996). Comprehension, coherence, and strategies in hypertext and linear text. In J.-F. Route, J.J. Levonen, A. Dillon & R.J. Spiro (Eds.), *Hypertext and Cognition* (pp. 109-136). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Foss, C. (1989). Tools for reading and browsing hypertext. *Information Processing Management, 25,* 407-418.

Garhart, C. & Hannafin, M. (1986). The accuracy of cognitive monitoring during computer-based instruction. *Journal of Computer-Based Instruction, 13,* 88-93.

Gay, G. (1986). Interaction of learner control and prior understanding in computer-assisted video instruction. *Journal of Educational Psychology, 78,* 225-227.

Glenberg, A.H., Sanocki, T., Epstein, W. & Morris, C. (1987). Enhancing calibration of comprehension. *Journal of Experiemnal Psychology, General, 116,* 119-136.

Glenberg, A.H., Wilkinson, A. & Epstein, W. (1982). The illusion of knowing: failure in the assessment of comprehension. *Memory and Cognition, 10,* 597-602.

Goetzfried, L. & Hannafin, M.J. (1985). The effect of the locus of CAI control strategies on the learning of mathematics rules. *American Educational Research Journal, 22,* 273-278.

Golledge, R.G., Dougherty, V. & Bell, S. (1995). Acquiring spatial knowledge: survey versus route-based knowledge in unfamilair environments. *Annals of the Association of American Geographers, 85,* 134-158.

Gomez, L.M., Egan, D.E., Wheeler, E.A., Sharma, D.K. & Gruchacz, A.M. (1983). How interface design determines who has difficulty learning to use a text editor. In *Proceedings of CHI Conference on Human-Computer Interaction,* (pp. 176-181). Boston, New York: ACM.

Gordon, S., Gustavel, J., Moore, J. & Hankey, J. (1988). The effects of hypertext on reader knowledge representations. In *Proceedings of The Human Factors Society - 32nd Annual Meeting*, . Anaheim:

Gray, S.H. (1987). The effect of sequence control on computer assisted learning. *Journal of Computer Based Instruction, 14*, 54-56.

Gray, S.H. (1990). Using protocol analysis and drawing to study mental model construction during hypertext navigation. *International Journal of Human-Computer Interaction, 2*, 359-377.

Gupta, M. & Gramopadhye, A.K. (1995). An evaluation of different navigational tools in using hypertext. *Computers and Industrial Engineering, 29*, 437-441.

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

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

Hayes, N.A. & Broadbent, D.E. (1988). Two modes of learning for interactive tasks. *Cognition, 28*, 249-276.

Hirtle, S.C. & Hudson, J. (1991). Aquisition of spatial knowledge for routes. *Journal of Environmental Psychology, 11*, 335-345.

Jacobs, G. (1992). Hypermedia and discovery-based learning: a historical perspective. *British Journal of Educational Technology, 23*, 113-121.

Jacobson, M.J. & Spiro, R.J. (1991). Hypertext learning environments and cognitive flexibility: characteristics promoting the transfer of complex knowledge. In *Proceedings of the International Conference on Learning Sciences*, . Association for Advancement of Computing in Education.

Jaynes, J.T. (1989). Limited freedom: linear reflections on nonlinear texts. In Barret. E (Ed) *The society of text: hypertext, hypermedia, and the social construction of information.* MIT Press, Cambridge Mass.

Johansen, K.L. & Tennyson, R.D. (1983). Effects of adaptive advisement on perception in learner-controlled, computer-based instruction using a rule learning task. *Educational Communications and Technology Journal, 31,* 226-236.

Jonassen, D. (1989). *Hypertext/hypermedia.* Englewood Cliffs, NJ: Educational Technology Publications.

Just, M. & Carpenter, P. (1987). *The psychology of reading and language comprehension.* Boston, MA: Allyn and Bacon.

Kieras, D. (1980). Initial mention as a signal to thematic content in technical passages. *Memory and Cognition, 8,* 345-353.

Kieras, D. (1985). *The role of prior knowledge in operating equipment from written instructions* University of Michigan, Ann Arbor.

Kim, H. & Hirtle, S.C. (1995). Spatial metaphors and disorientation in hypertext browsing. *Behaviour and Information Technology, 14,* 239-250.

Kintsch, E. (1990). Macroprocesses and microprocesses in the development of summarization skill. *Cognition and Instruction, 7,* 161-195.

Kintsch, W. (1994). Text comprehension, memory, and learning. *American Psychologist. 49 (4) 294-303.*

Kintsch, W. & Yarbrough, J.C. (1982). Role of rhetorical structure in text comprehension. *Journal of Educational Psychology, 74,* 828-834.

Kinzie, M.B. & Sullivan, H.J. (1989). Continuing motivation, learner control and CAI. *Educational Technology Research and Development, 37,* 5-14.

Kitchin, R.M. (1994). Cognitive maps: what are they and why study them? *Journal of Environmental Psychology, 14,* 1-19.

Knuth, R.A. & Brush, T.A. (1989). Results of the hypertext'89 design survey. *Hypermedia, 2,* 91-107.

Kommers, P.A.M. (1990). *Hypertext and the acquisition of knowledge.* Unpublished PhD Thesis. University of Twente. The Netherlands.

Lee, S.S. & Lee, Y.H.K. (1991). Effects of learner-control versus program control stratgeies on computr-aided learning of chemistry problems: for acquisition or review? *Journal of Educational Psychology, 83,* 491-498.

Large, A. (1996). Hypertext instructional programs and learner control: a research review. *Education for Information, 14,* 95-106.

Leventhal, L.M., Teasley, B.M., Instone, K., Rohlman, D.S. & Farhat, J. (1993). Sleuthing in HyperHolmes: an evaluation of hypertext vs. a book to answer questions. *Behaviour and Information Technology, 12,* 149-164.

Locatis, C., Letourneau, G. & Banvard, R. (1989). Hypermedia and instruction. *Educational Technology Research and Development, 37,* 65-77.

Mandl, H., Picard, E., Henninger, M. & Schnotz, W. (1991). *Knowledge acquisition with texts by means of flexible computer-assisted information access.* Technical Report 54, Deutsches Institute. University of Tubingen. Germany.

Mannes, S.M. & Kintsch, W. (1987). Knowledge organisation and text organisation. *Cognition and Instruction, 4,* 91-115.

Mayer, R.E. (1976). Some conditions of meaningful learning for computer programming: advance organisers and subjects control of frame order. *Journal of Educational Psychology, 68,* 143-150.

Mayes, J.T., Kibby, M.R. & Anderson, T. (1990a). Learning about learning from hypertext. In D.H. Jonassen & H. Mandl (Eds.), *Designing Hypermedia for Learning.* Springer-Verlag.

Mayes, J.T., Kibby, M.R. & Anderson, T. (1990b). Signposts for conceptual orientation: some requirements for learning from hypertext. In R. McAleese & C. Green (Eds.), *Hypertext: State of the Art*

McAleese, R. (1989). Navigation and browsing in hypertext. In R. McAleese (Ed.), *Hypertext: Theory into Practice.* (pp. 5-38). Oxford: Intellect.

McAleese, R. (1990). Concepts as hypertext nodes: the ability to learn while navigating through hypertext nets. In D. Jonassen and H. Mandl (Eds) *Designing Hypermedia for Learning.* Berlin: Springer-Verlag.

McGrath, D. (1992). Hypertext, CAI, paper, or program control: do learners benefit from choices? *Journal of Research on Computing in Education, 24,* 513-532.

McKnight, C., Dillon, A. & Richardson, J. (1990). A comparison of linear and hypertext formats in Information Retrieval. In R. McAleese & C. Green (Eds.), *Hypertext: State of the Art.* (pp. 11-19). Oxford: Intellect.

McKnight, C., Dillon, A. & Richardson, J. (1991). *Hypertext in context.* Cambridge: Cambridge University Press.

McNamara, D.S., Kintsch, E., Butler Songer, N. & Kintsch, W. (1996). Are good texts always better? Interactions of text coherence, background knowledge and levels of understanding in learning from text. *Cognition and Instruction, 14,* 1-43.

Merrill, M.D. (1975). Learner control: beyond aptitude-treatment interactions. *AV Communications Review, 23,* 217-226.

Moeser, S.D. (1988). Cognitive mapping in a complex building. *Environment and Behaviour, 20,* 21-49.

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. & Dix, A.J. (1988). A Comparison of hypertext, scrolling and folding as mechanisms for program browsing. In D.M. Jones & R. Winder (Eds.), *People and Computers IV* (pp. 421-436). Cambridge: Cambridge University Press.

Moravesik, J.E. & Kintsch, W. (1993). Writing quality, reading skills, and domain knowledge as factors in text comprehension. *Canadian Journal of Experimental Psychology, 47,* 360-374.

Nelson, T.H. (1987). *Literary machines.* San Antonio, Texas:

Papert, S. (1980). *Mindstorms: children, computers and powerful ideas.* Basic Books, New York.

Parunak, H.V. (1989). Hypermedia topologies and user navigation. In *Hypertext'89 Proceedings,* (pp. 43-50).

Peterson, P.L. & Janicki, T. (1979). Individual characteristics and children's learning in large group and small group approaches. *Journal of Educational Psychology, 71,* 677-687.

Rada, R. & 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).

Reinking, D. & Rickman, S.S. (1990). The effects of computer-mediated text on the vocabulary learning and comprehension of intermediate grade readers. *Journal of Reading Behaviour, 12,* 395-411.

Ross, S.M., Morrison, G.R. & O'Dell, J.K. (1989). Uses and effects of learner control of context and instructional support in computer-based instruction. *Educational Technoogy Research and Development, 37,* 29-39.

Ross, S.M. & Rakow, E.A. (1982). Learner control versus program control as adaptive strategies for selection of instructional support on math rules. *Journal of Educational Psychology, 73,* 745-753.

Rouet, J.-F. & Levonen, J.L. (1996). Studying and learning with hypertext: empirical studies and their implications. In J.-F. Route, J.J. Levonen, A. Dillon & R.J. Spiro (Eds.), *Hypertext and Cognition* (pp. 9-24). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Rouet, J.F. (1992). Cognitive processing of hyperdocuments: when does nonlinearity help? In *Proceedings of the 4th ACM Conference on Hypertext,* . Milan:

Scardamalia, M. & Bereiter, C. (1991). Literate expertise. In K.A. Ericsson & J. Smith (Eds.), *Toward a General Theory of Expertise: prospects and limits* Cambridge: Cambridge University Press.

Schank, R.C. (1993). Learning via multimedia computers. *Technology in Education, 36,* 54-56.

Schmidt, R.A. & Bjork, R.A. (1992). New conceptualisations of practice: common principles in three paradigms suggests new concepts for training. *Psychological Science, 3,* 207-217.

Shin, C.E., Schallert, D.L. & 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.* San Francisco: Addison Wesley.

Siegal, R. & White, T. (1975). The developmemt of spatial representations of large scale environments. In H.W. Reese (Ed.), *Advances in Child Development and Behaviour* New York: Academic Press.

Simpson, A. & McKnight, C. (1990). Navigation in hypertext: structural cues and mental maps. In R. McAleese & C. Green (Eds.), *Hypertext: State of the Art.* (pp. 73-83). Oxford: Intellect.

Small, R.V. & Grabowski, B.L. (1992). An exploratory study of inforamtion seeking behaviours and learning with hypermedia information systems. *Journal of Educational Multimedia and Hypermedia, 1,* 445-464.

Smith, P.A. & Wilson, J.R. (1993). Navigation in hypertext Through Virtual Environments. *Applied Ergonomics, 24,* 271-278.

Snow, R.E. & Peterson, P. (1980). Recognising differences in student aptitudes. In W. McKeachie (Ed.), *New Directions for Teaching and Learning, Cognition, and College Teaching* (pp. 1-23). San Francisco: Jossey-Bass.

Spiro, R.J., Feltovitch, P.J., Jacobson, M.J. & Coulson, R.J. (1991). Cognitive flexibility, constructivism and hypertext: random access instruction for advanced knowledge acquisition in ill-structured domains. *Educational Technology, 31,* 24-33.

Spring, C. (1985). Comprehension and study strategies reported by university freshmen who are good and poor readers. *Instructional Science, 14,* 157-67.

Stanton, N.A. (1994). Explorations into hypertext: spatial metaphor considered harmful. *Educational and Training Technology International, 31,* 276-294.

Stanton, N. & Baber, C. (1992). An investigation of styles and strategies in self-directed learning. *Journal of Educational Multimedia and Hypermedia, 1,* 147-167.

Stanton, N.A., Taylor, R.G. & Tweedie, L.A. (1992). Maps as navigational aids in hypertext environments: an empirical evaluation. *Journal of Educational Multimedia and Hypermedia, 1,* 431-444.

Stevenson, R. (1993). *Language, thought, and representation.* Chichester: J. Wiley & Sons.

Stevenson, R.J. & Palmer, J.A. (1994). *Learning: principles, processes, and practices.* Cassell.

Thorndyke, P.W. & Hayes-Roth, B. (1982). Differences in spatial knowledge acquired from maps and navigation. *Cognitive Psychology, 14,* 560-589.

Thuring, M., Hannemann, J. & Haake, J.M. (1995). Hypermedia and cognition: designing for comprehension. *Communications of the ACM, 38,* 57-66.

Tobias, S. (1972). *Preference for instructional method and achievement.* Paper presented to Eastern Psychological Association.

Tripp, S.D. & Roby, W. (1990). Orientation and disorientation in a hypertext lexicon. *Journal of Computer-Based Instruction., 17,* 120-124.

Tversky, B. (1992). Distortions in cognitive maps. *Geoforum, 23,* 131-138.

van Dijk, T.A. & Kintsch, W. (1983). *Strategies of discourse comprehension.* Orlando: Academic Press.

Watts, J. (1994). Navigation in the computer medium: a cognitive analysis. In *Proceedings of the Human factors and Ergonomics Society* 38th Annual Meeting,

Wenger, M.J. & Payne, D.G. (1994). Effects of a graphical browser on readers' efficiency in reading hypertext. *Technical Communication, 41,* 224-233.

Wickens, C.D. (1984). *Engineering psychology and human performance.* Harper Collins.

Wickens, C.D. (1990). Navigational ergonomics. In *Proceedings of the Ergonomics Society's Annual Conference,* (pp. 3-6). Leeds, England:

Williams, M. (1993). A comprehensive review of learner control: the role of learner characteristcs. In *Proceedings of the Annual conference of the Association for Educational Communications and Technology,* . New Orleans: Association for Educational communications and Technology.

Woods, D.D. (1984). Visual momentum: a concept to improve the cognitive coupling of person and computer. *International Journal of Man-Machine Studies, 21,* 229-244.

Wright, P. (1991). Cognitive overheads and prostheses: some issues in evaluating hypertexts. In *Hypertext'91 Proceedings,* (pp. 1-12).

Wright, P. (1993). To jump or not to jump: strategy selection while reading electronic texts. In C. McKnight, A. Dillon & J. Richardson (Eds.), *Hypertext: a psychological perspective* (pp. 137-152). London: Ellis Horwood.

Wright, P. & Lickorish, A. (1991). An empirical comparison of two navigation systems for two hypertexts. In R. McAleese & C. Green (Eds.), *Hypertext: State of the Art*

Young, J.D. (1996). The effect of self-regulated learning strategies on perfromacne in learner controlled computer-based instruction. *Educational Technology: Research and Development, 44,* 17-27.

A

Learning text

The Nature of Human Learning.

The aim of this discussion is to examine the complex nature of human learning. In particular we will focus our attention on people's capacity for explicit, deliberate learning, an ability that is unique to our species.

Click on the green button to begin.

Begin

Human Learning.

Human beings engage in two different kinds of learning: implicit and explicit. Implicit learning occurs without our being aware of it, whereas explicit learning requires conscious and deliberate effort.

Implicit learning involves noticing regularities in the world and responding to them in consistent ways, and it is an ability found in all anilmals. Such learning is usually referred to as conditioning when animal learning is discussed. The knowledge gained through implicit learning is itself implicit and inaccessible to conscious awareness. We use the knowledge to act in the world but we cannot describe it. The ease with which we use language and act in the world reveal the extent of our implcit knowledge.

Our capacity for explicit learning reveals a vast potential for learning that few people ever fully achieve. The discussion that follows will focus on explicit learning.

Previous Next

Explicit Learning.

Explicit learning requires conscious and deliberate thought. It seems to be unique to humans. Explicit learning is the kind of learning that is fostered in schools and other educational establishments and because of the importance that we place on education, we concentrate here on spelling out what it involves. We can identify three different kinds of explicit learning: understanding; problem solving; and memorising.

In each case though, explicit learning is made possible through the use of memory.

Previous Next

The Role of Memory in Learning.

Human memory can be thought of as having two functions. One is to store all the knowledge we have gained about the world as concepts, facts, and episodes. The other is to provide a place where conscious thinking can occur. The first, storage function is fulfilled by long term memory, a memory store that holds everything we know and believe about the world. The second function is fulfilled by a working memory (Baddeley and Hitch, 1974; Baddeley, 1986).

Previous Next

Long Term Memory.

Long term memory is a memory store of infinite capacity. It holds everything we know and believe about the world as facts, concepts, and episodes. One of the goals of long term memory is to transfer new information from working memory to long term memory, having first evaluated the new information in the light of pre-existing knowlege.

Previous Next

Working Memory.

Working memory is a mental workspace where conscious thinking occurs. It has a storage function because we need to hold in working memory the ideas that we are thinking about. One of the main features of conscious thought is that it is only possible to follow one train of thought at a time. This is because working memory where such thinking takes place has a limited capacity; it can only hold a small number of ideas at a time, (7 plus or minus 2, Miller, 1956). This places severe constraints on explicit learning because it can be easily overloaded. Hence, explicit learning is difficult because its demands may exceed the capacity of working memory. Our discussion of the three different types of explicit learning: understanding, problem solving, and memorisation.

Previous Next

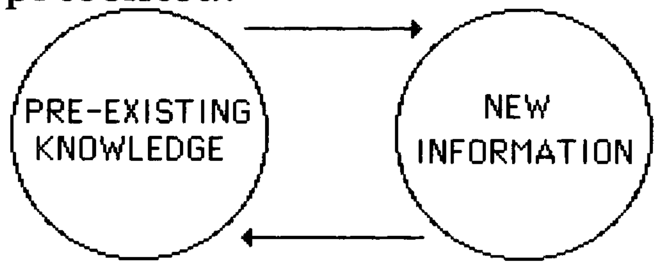
Learning as Understanding.

Understanding is the most difficult form of explicit learning. First, like all explicit learning, it requires working memory and, indeed, often exceeds the limits of memory. Second, it requires an ability not required by other forms of explicit learning. This is the ability to reflect on and deliberately control one's own knowledge and thought processes (Metacognitive Skills). Such self-reflection is a very high level cognitive activity that usually takes many years to achieve. Third, it is hard to pin down exactly what is meant by the term understanding, and to explain how such understanding is achieved. However, Scardamalia and Bereiter (1991) have attempted to provide an in-depth account of what is meant by the term understanding.

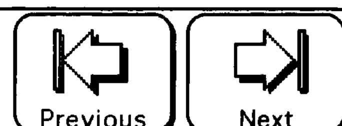
Previous Next

Scardamalia and Bereiter's Model

Scardamalia and Bereiter (1991) point out that there are two elements involved in learning, one's pre-existing knowledge and the new information being presented.



Understanding is seen as a two-way interchange between the two elements. Pre-existing knowledge is used to interpret new material and, in turn, the new material yields information that may be used to modify our pre-existing knowledge. The aspect that is most likely to be neglected is the journey from right to left in the diagram above. People often fail to evaluate their pre-existing knowledge in the light of new material, meaning that they may hold conflicting beliefs because they learn new information which is inconsistent with their pre-existing knowledge, having failed to complete the process of evaluation. Small wonder, therefore, that people find learning through understanding so difficult.



Metacognitive skills

The term metacognition is used to refer to two related abilities. One concerns having explicit knowledge of learning strategies and of one's own learning processes. The other concerns the ability to use comprehension strategies by monitoring and controlling one's own thinking and learning.

Metacognitve processes are of critical imporatance for conceptual understanding, because if true understanding is to occur the learner must be able to relflect upon and update their pre-existing thoughts and ideas in the light of the new information they wish to learn, As well as evaluating the new information in the light of pre-existing knowledge.

Previous Next

Learning Through Understanding.

Learning through understanding involves deliberate attempts to make sense of new material by using prior knowledge and deliberate attempts to rethink one's ideas in the light of new material. Explicit understanding involves the deliberate use of pre-existing knowledge to interpret new material as in the use of analogies and the deliberate use of the new material to modify and update pre-existing beliefs and ideas.

Previous Next

Analogical Thinking.

Analogical thinking is used when a problem solver attempts to use the structure of the solution to a familiar problem to guide the solution of a new problem. Research evidence suggests that analogical thinking involves four component processes:

(1) Interpretation and representation of the target problem.

(2) The retrieval or selection of a plausibly useful source analogue.

(3) Mapping elements of the source analogue onto the target problem.

(4) The transfer of inferences from the source to the target domain.

A number of models of analogical thinking have been built around these processes. Our discussion will focus on the pragmatic model of analogical thinking.

Previous Next

The Pragmatic Model of Analogical Thinking.

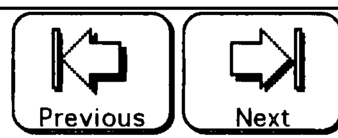
Holyoak and Thagard's pragmatic model is a constraint satisfaction model of analogue retrieval and mapping. They argue that both the retrieval of a suitable source analogue and completing a successful mapping are subject to the multiple, and parallel constraints of structure, semantics and pragmatics. These ensure that the source analogue that is retrieved and mapped onto the target is similar to the target in structure, content and overall goals. When all these constraints are satisfied, an analogy is retrieved and mapped onto the target problem.

Previous Next

Structural Constraints.

Gentner (1983) has emphasized the importance of structural constraints for successful mapping of a source analogy to a target problem. Structural similarity between problems ocurs when they both have the same propositional structure. However, Holyoak and Thagard (1990) suggest that structural similarity alone may over generate candidate analogies because they allow mapping of analogies that have the same propositional structure, even if they are semantically dissimilar (have different meanings and are so incompatible).

For example, *John is taller than Bill, and Bill is taller than Sam* is structurally similar to *Mary is heavier than Sue, and Sue is heavier than Beth.* The propsistions in each statement are isomorphic. In this case they are also semantically similar. Yet there is an equally valid isomorphism between the first analogy and *Communism is more radical than socialism, and socialism is more radical than capitalism.* But here the analogy does not work because, despite the structural similarity, there is no semantic similarity between the two statements. This demonstrates the importance of semantic constraints.



Semantic Constraints.

Semantic constraints ensure that propositions in the target and source domain are semantically similar. Holyoak and Koh argue that semantic similarity is the major constraint on retrieval, while structural similarity is more important for mapping.

Previous Next

Pragmatic Constraints.

Pragmatic constraints ensure that the goals of the problem solver help both retrieval and mapping of a source analogue. A number of different types of pragmatic constraints have been proposed. E.G. Winston (1980) has emphasized the importance of causal knowledge, while others have focused on the roles of high level plans and functional knowledge. Pragmatic constraints favour correspondences that are pragmatically important to the problem solver. An element may be judged important that some mapping for it should be found. Alternatively, a particular correspondence between two elements may be presumed to hold and so determine the inferences that are made. E.g. Suppose someone is assessing the nature of the Contras' attempt to overthrow the government of Nicaragua, and is considering both Hungary and Israel source analogues. The Hungary analogue categorizes the Hungarians as freedom fighters and the USA support them. The Israel analogue categorizes the PLO as terrorists and the USA does not support them. Now suppose that the problem solver is motivated to support the Contras. this can be regarded as a presumed correspondence, and hence will be treated as an additional mapping between the Contras target and the Hungary source increasing the likelihood that this source will be used.
But what does this tell us about the processes involved in learning through understanding ?

Previous Next

Summary of Learning as Understanding.

Learning through understanding consists of evaluation as well as the integration of new information with old. The new learning is evaluated in relation to pre-existing knowledge, while the pre-existing knowledge itself is evaluated in the light of new learning. Such evaluations are very difficult, primarily because they require conscious attention (the use of working memory) and the deliberate use of one's pre-existing knowledge.

The main way in which prior knowledge can be used to evaluate new material is through the use of analogies, where a similar situation is retrieved from memory and used to interpret the new material. Analogical thinking is subject to syntactic, semantic, and pragmatic constraints, and is difficult to use without explicit instruction.

Previous Next

Learning as Problem Solving.

Problem solving is a common human activity. Since it does not require the deliberate use and explicit awareness of prior knowledge like understanding does, people engage in it readily, sometimes at the expense of understanding.

A problem is a situation in which the goal is blocked. Whenever you carry out some action to achieve the goal, the problem is solved. In reaching the solution something new is learned. Then, when the problem occurs again, the same solution will be remembered and used again. With repeated practice of the same problem, the solution will come to be retrieved from long term memory rapidly and automatically whenever the problem is encountered. But what exactly is involved in problem solving ?

Previous Next

Solving Problems.

The problems we are routinely faced with are so diverse that it seems reasonable to suppose that there is a small set of general purpose rules which are applied to each new problem that arises. This is the view that has been taken by the information processors (e.g. Newell and Simon, 1972) in their work on problem solving.

The information processors have confined themselves to well defined problems, such as mathematical problems, in which the component steps in the solution can be explicitly described. However, if learning through problem solving is to occur, this solution needs to be practised so that it becomes automatic or implicit.

Previous Next

The Information Processors.

Newell and Simon (1972) developed their Information Processing theory from an analysis of verbal protocols (transcripts of subjects thinking aloud whilst problem solving). These reports provided an in-depth analysis of the strategies people use when deriving solutions to problems. In order to provide a framework of human problem solving Newell and Simon suggest that the problem solving process is characterised by a series of states of knowledge through which the individual passes between the initial and goal states, and by a set of operations which move him/her from one state to another.

Previous Next

The Human Information Processor.

Newell and Simon suggest that the human information processing system solves problems by converting the input into a representation of the problem space, which is held in short term memory. Production rules are stored in long term memory and the ones that are relevant to the problem are retrieved during comprehension and also form part of the representation in short term memory. The production rules convert the representation of the initial state into the goal state so that a response can be made.

Problem solving is seen as consisting of a translation of the input into an internal representation of the problem. Problem solving methods are then applied to this representation to yield a solution.

Previous Next

Problem Translation.

Problem translation is an attempt to represent a problem structure in an objective way, this representation is sometimes referred to as the task environment. A complete understanding of a problem task environment can be equated with an understanding of all the ways in which that problem could be presented. The problem structure itself constrains the processes of problem solving in that it contains information about what needs to be done in order to solve the problem. There is a large body of evidence that has emphasised the importance of the way a problem is interpreted in the task environment for attaining a solution.

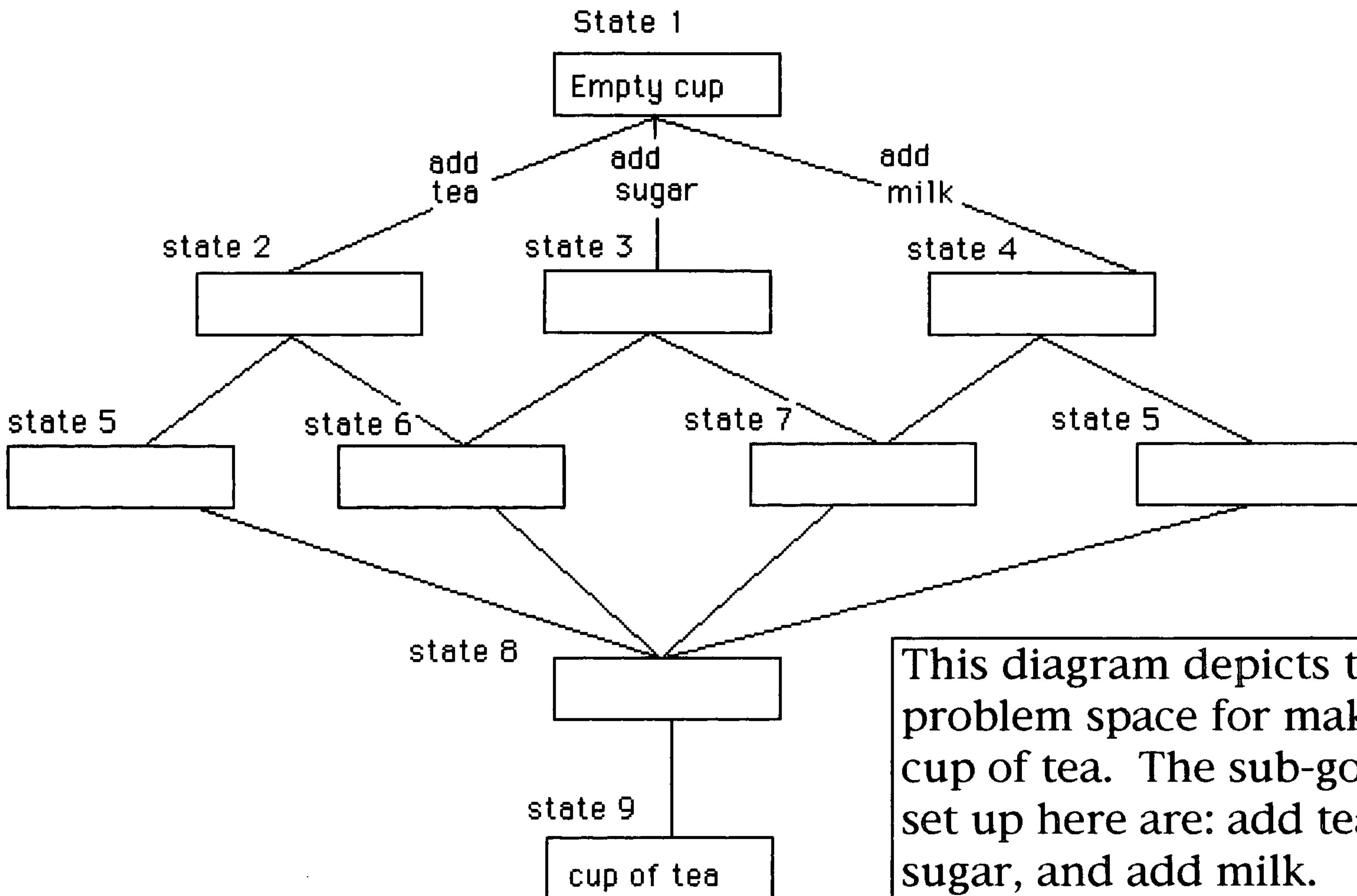
Previous Next

Problem Representation.

In order to solve problems people must construct a mental representation of the problem information. This representation is called the problem space, consisting of states and operators that convert one state into another. For example, when making a cup of tea (see diagram of the problem space) the initial state is the empty cup. This initial state is converted into another state (say having tea in the cup) by the operator "add tea". Then this second state can be converted into another state (say having sugar) and so on until the goal state is reached.

Previous Next

The Problem Space.



This diagram depicts the problem space for making a cup of tea. The sub-goals set up here are: add tea, add sugar, and add milk.

Previous Next

Problem Solving Methods.

Newell and Simon propose that there are a small number of general purpose, strategies or heuristics that can be used to solve any kind of problem.

Heuristics are rules of thumb which usually give the correct solution although this cannot be guaranteed. They are to be distinguished from algorithms, which guarantee that the correct solution to a problem will be found. The information processors emphasise a heuristic known as means-end analysis.

Previous Next

Means-Ends Analysis.

Means-ends analysis involves breaking a problem down into sub-problems and tackling each sub-problem using a difference reduction strategy. The general feature is that the current state is matched against the goal state and if there are differences between the two, a sub-goal is set up to eliminate the difference. As each sub-goal is met, the procedure is repeated until the current state matches the goal state. For example, when making a cup of tea, the initial state (the empty cup) is compared to the goal state (the cup of tea). One way to reduce this difference is to set up a sub-goal (add tea to the cup). The resulting state is then compared to the goal state again, and another sub-goal is set up say (add sugar) and so on until the goal state is reached.

Newell and Simon research has led them to draw a number of important conclusions about the nature of human problem solving. So, what are the main assertions of the information processing theory ?

Previous Next

Summary of the Information Processors.

Newell and Simon's approach emphasises the importance of an accurate mental representation of the problem that is to be solved. The construction of this mental representation - the problem space, is probably the most important aspect of the problem solving process. This means that if the problem space does not include the right elements, and a clear specification of the problem goal, it may be inadequate for the attainment of the solution. It is this factor according to Newell and Simon that differentiates a good problem solver from a poor one.

Previous Next

Problem Solving and Learning.

Once the solution to a problem has been found it needs to be practised so that when the same problem occurs again the solution will be retrieved automatically.

Problem solving can be very demanding when so much information has to be held in memory until the solution is reached. Thus learning also involves finding a way to reduce this load on memory so that the problem can be solved more easily. Such learning occurs with repeated attempts to solve the problem. That is, learning occurs as a result of practice.

Previous Next

Anderson's Model of Skill Acquisition.

The view of learning to do things automatically is based on Anderson's (1983) model of skill acquisition. According to Anderson, skills are learned as a result of practice and they become automatic when highly specific rules that give the solution directly are stored in memory. In the process of acquiring such specific rules, other rules, rules that describe the way the solution is achieved are also stored in memory. These additional rules remain available in memory and can be used when needed. Their strength is determined by the number of times they are used. Despite the obvious advantages to problem solving as a form of learning, it also has some inherent dangers.

Previous Next

Problems with Problem Solving.

The main problem with problem solving as a form of learning is that it can lead to a neglect of understanding. This is a serious problem because automatic skills learned through problem solving can only be used in the situation in which they were learned. This means that there is no generalization to new situations, unless they are very similar to the original learning situation. Generalization is what enables new learning to be used in novel situations. For good generalisation to occur, one needs to understand underlying conceptual principles. These conceptual principles will underlie a whole range of problems that seem on the surface to be very different. Hence by understanding these principles, a whole range of problems can be tackled in a similar manner.

Previous Next

The Neglect of Conceptual Understanding.

A preoccupation with problem solving may lead to a neglect of understanding because both require the use of working memory. Problem solving is effortful because of its excessive demands on working memory. The search for understanding is also effortful for the same reason. So if you are doing one kind of learning you cannot also be doing the other. So what are the benefits of learning through problem solving ?

Previous Next

Summary of Learning as Problem Solving.

Problem solving results in learning when a novel solution is found to a problem. Further learning occurs when the solution is used repeatedly to solve the problem until it can be retrieved from long term memory automatically without using working memory. Thus working memory capacity is freed up and becomes available for further learning. However, if working memory is occupied by problem solving activities, it cannot also be used for understanding. One solution to this 'bottleneck' is to evaluate the plausibility of an answer to a problem, thus searching for understanding once the problem has been solved.

Previous Next

Learning as Memorisation.

Memorisation is involved whenever a person reads or listens to material with the intention to memorise it. Typical forms of memorisation are rehearsal and repetition. However, other more sophisticated techniques are also possible, for example organising the material according to some conceptual principle. These techniques involve the integration of the new material with pre-existing knowledge. Memorisation results in the accumulation of information in memory. In contrast to understanding, memorisation does not change or modify either the new material or existing knowledge in any way.

Previous Next

Rehearsal.

Two important kinds of rehearsal are Maintenance Rehearsal and Elaborative Rehearsal. Maintenance rehearsal simply maintains or holds information without transforming it into a deeper longer-lasting code. This process is thought to prevent forgetting, but does not lead to long-term learning.

Long term learning was assumed by Craik and Lockhart to depend upon Elaborative rehearsal, a process that leads to an increase in the depth at which an item is encoded. Thus maintenance rehearsal alone is not a successful memory technique. Learning and memory are improved if subjects can organise the material in some way and integrate it with pre-existing knowledge.

Previous Next

Organisation and Clustering.

An example of the importance of organisation comes from a series of studies by Tulving (1962). Tulving had subjects listen to a list of 16 unrelated words and then asked them to recall as many of the words as possible, in any order they wished. After a subject had remembered as many words as possible, the list was presented again, with the words in a different order. This procedure was repeated 16 times, with the words in a different order each time they were presented. In spite of the differing order for each presentation, most subjects tended to recall the same set of words together each time they remembered them. Further, for most subjects, the incidence of this clustering increased systematically from trial to trial. These results show that the more a person tries to organise the information the better they will remember the information. This view was developed by Craik and Lockhart (1972) who proposed the levels of processing view of memory.

Previous Next

Levels of Processing.

Craik and Lockhart argued that the strength of a memory depended on the level (or depth) of processing carried out on the information. The deeper the processing, the more durable the memory trace. Depth of processing ranged from a very shallow analysis of physical features such as pitch and loudness, to a deep semantic analysis of the meaning of the information. Craik and Tulving (1985) carried out a number of important experiments from a levels of processing perspective.

Previous Next

Craik and Tulving's Experimental Results.

Craik and Tulving's basic finding, was that the deeper the level of processing the better the words were remembered. They also found that the degree of semantic processing also effected recall. The degree of semantic processing depended on integration and elaboration.

Despite the fact that these results have been replicated many times, the levels of processing perspective does have a number of problems, and some important implications for learning.

Previous Next

Integration.

Integration refers to the integration of new information with prior knowledge. Deep semantic processing requires new information to be interpreted with the use of prior knowledge the words that were processed at the semantic level required integration with prior knowledge and were remembered best.

Thus, the greater the integration with prior knowledge the better was the memory for a word.

Previous Next

Elaboration.

Elaboration refers to the extent to which the memory representation of a word is elaborated. Deep elaborative encoding appears to enhance memory because it sets up memory traces that are more discriminable than items that have been encoded shallowly and with little elaboration.

Previous Next

Problems with Levels of Processing.

Despite it's enormous conribution to the field of cognitive psychology the levels of processing approach has a number of theoretical and practical problems. Including Transfer Appropriate Processing and the problem of measurement.

Previous Next

The Problem of Measurement.

Probably the most serious problem with Levels of Processing is the difficulty of measuring or defining depth independently of the actual memory score (Baddeley (1978).

For example, if 'depth' is defined as 'how many words are remembered' and if 'how many words are remembered' is taken as a measure of depth, we are faced with a circular definition.

Craik and Tulving (1975) did try to tackle this problem but their efforts were unsuccessful, and there is still no generally accepted way of independently measuring depth of processing. This problem limits the powerfulness of the Levels of Processing approach.

Previous Next

Transfer Appropriate Processing.

Levels of Processing has been criticised on the grounds that it over concentrates on encoding, without specifying the relevant retrieval conditions (Morris, Bransford, and Franks, 1977).

Morris et al stressed that the best means of encoding material will depend on the retrieval conditions that are expected. They referred to this process as "Transfer Appropriate Processing". For example, if you were trying to teach students phonetics, it would be most appropriate to focus on features such as the sound of words rather than their meaning. This form of encoding could be regarded as shallow for one purpose but very meaningful and appropriate for another. Morris et al illustrated this process with an experiment not that dissimilar from the original Craik and Tulving experiments.

Previous Next

Implications for Learning.

The levels of processing approach has two important implications for learning. First, it highlights the importance of deep semantic processing, that is, of integration and elaboration. In particular, it lays the groundwork for learning through understanding. In order to make explicit use of learned material, such material has to be easily accessible. Deep processing will make it more accessible. Second, the work highlights the fact that people frequently fail to use optimal learning strategies when they are deliberately trying to memorise material. That is, the focus of memorisation is on getting the material into memory and keeping it there, and this may lead to the neglect of integration with prior knowledge.

Previous Next

Summary of Learning as Memorisation.

Memorisation leads to a concern with the accumulation of information rather than with understanding that information. While memorisation may involve the use of prior knowledge to interpret new material (as shown in Tulving's clustering experiments), it lacks the evaluative component that is part of understanding and that may lead to extensive revision and reorganisation of pre-existing knowledge. Memorisation, therefore, is not the best way of trying to learn new material. However, new learning is best achieved through understanding; memorisation can then be used to consolidate such learning.

So, what have we learned about the nature of human learning?

Previous Next

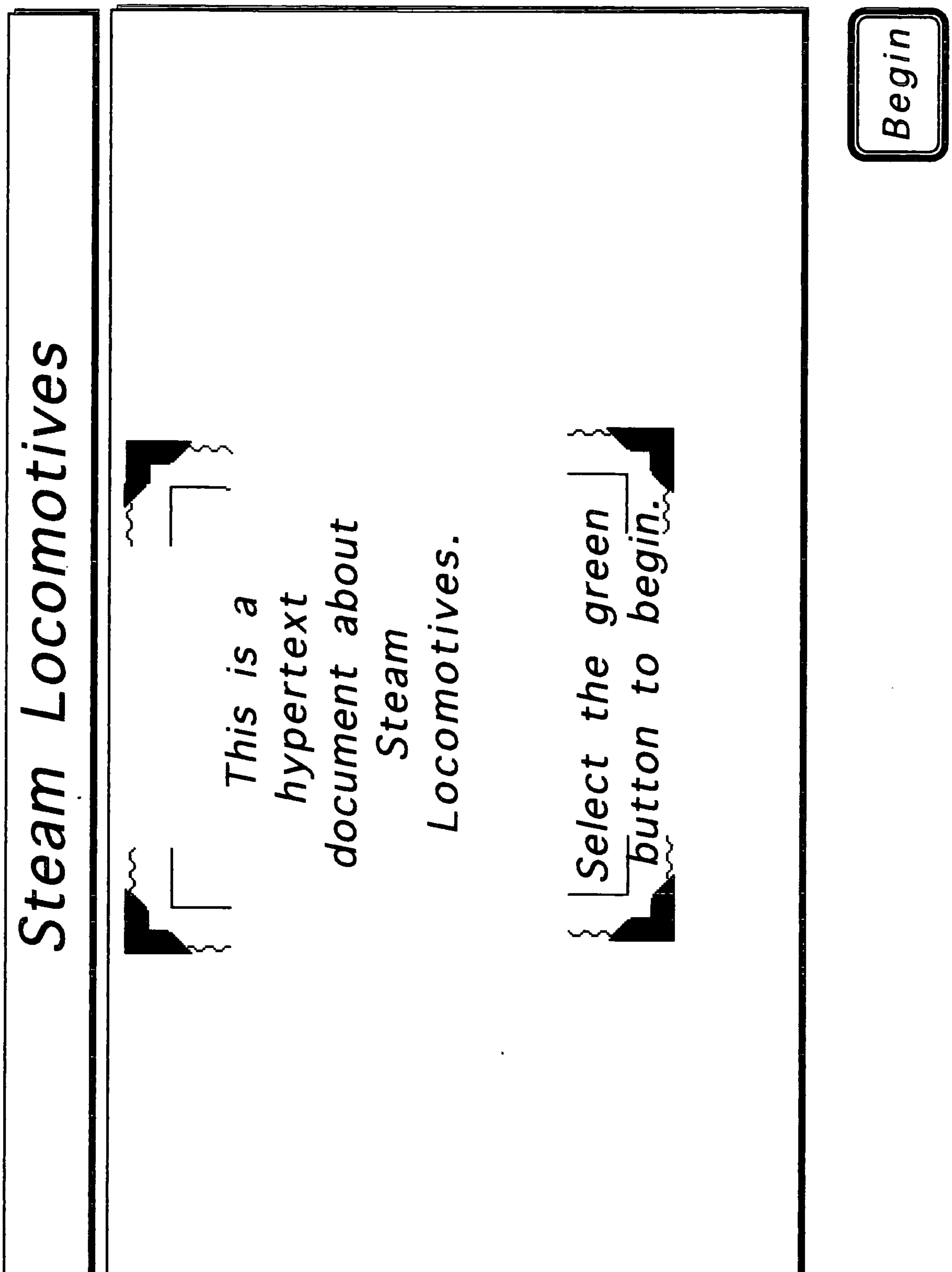
Conclusion.

Explicit learning occurs through understanding, problem solving and memorisation. Since explicit learning is conscious, it requires the use of working memory and deliberate effort. Understanding is the most difficult form of explicit learning, as it depends on the deliberate use of pre-existing knowledge to interpret and evaluate incoming information and also on the deliberate use of incoming information to evaluate and revise pre-existing knowledge. Understanding is the most important form of explicit learning, since it is responsible for our ability to generalize what we have learned to new situations. However, because of its difficulty, it is often side-stepped and replaced by problem solving or memorisation.

Previous

B

Steam text


Steam Locomotives
This is a hypertext document about Steam Locomotives.
Select the green button to begin.
Begin

Introduction

For a hundred years the steam locomotive was the prime mover of people and freight. It faithfully served the railway industry until it was replaced by diesel and electric traction. This text explores how the steam locomotive works, describes the components of the steam locomotive, and a brief survey of locomotive design is also present.

Previous Next

How a Steam Loco Works

The workings of a steam locomotive are founded on straightforward concepts and engineering principles. Any understanding of how a steam locomotive works must begin with the properties of steam itself, and how steam is converted into the kinetic energy of motion, in other words, the harnessing steam energy to produce locomotion.

Previous Next

Properties of Steam

When water is heated above boiling point it turns to steam and thereby expands to a volume 1700 times greater than it originaly was. If, however, the water is confined in a sealed vessel it cannot expand, therefore pressure rises. Water confined in a pressurised vessel boils at a higher temperature. At high pressures, a considerable amount of thermal energy is imparted to water to turn it into steam. The purpose of an engine is to convert the thermal energy possessed by the steam into the kinetic energy of motion.

Previous Next

Harnessing Steam Energy

An engine converts energy in one form (usually heat) into the energy of movement - kenetic energy. A steam engine is a form of heat engine wherein steam, the working fluid, possesses heat energy which manifests itself as pressure. By forcing steam pressure to act on a piston in a cylinder, the piston can be made to move: the basic mechansim of an engine. The world's first steam engines translated this idea into practice. It took 30 years of development to convert the technology of the stationary engine into a self-propelled steam engine. What we now call a locomotive.

Previous | Next

The First Steam Engines

The first steam engines, built by Thomas Newcomen (c.1712) and improved by James Watt (1774), were stationary engines, used typically for pumping water from mines. They consisted of a single, vertical cylinder in which a piston moved up and down to drive a pivoted beam.

Previous Next

Self-Propelled Steam Engines

A locomotive is a steam engine mounted on wheels where the work done by the engine is used to turn the wheels and propel the locomotive. However, it was not until 1829 that a truly succesful steam locomotive was produced; Stephenson's Rocket.

Previous Next

Stephenson's Rocket

At Rainhill in 1829, trials for a design of a locomotive to operate the Liverpool and Manchester Railway were held. George Stephenson's Rocket won a decisive victory by achieving speeds of 30mph. Demonstrating that at last, after many years of struggle, the age of the steam locomotive had finally arrived.

Rocket and her peers introduced all of the standard components of the steam locomotive as we know it.

Previous Next

The Components of the Steam Loco

Functionally, there are two separate parts to a steam locomotive: the boiler and the engine. The former produces steam and the latter uses steam to drive machinery to obtain motion.

Previous | Next

The Boiler

The purpose of the boiler is to generate steam in sufficient quantities and at sufficient pressure to power the locomotive.

The boiler has three distinct parts: the firebox, where fuel is burned to generate heat; the barrel, where water is heated to steam; and the smoke box, through which used steam and combustion gases from the fire are exhausted, via the chimney.

The usual boiler arrangement has the smoke box at the front, the barrel in the middle and the firebox at the end adjoining the cab, where the control systems are located.

Previous Next

Firebox

The firebox is a box with an inner and an outer casing in which the coal fire burns. The fire sits on a large grate formed of widely-spaced bars to allow free airflow. The gases produced by combustion are exhausted through flue tubes, which run the length of the boiler barrel, to the smoke box. Heat is transferred to the water through the outer surface of the firebox itself and through the surfaces of the flue tubes.

Previous Next

Barrel

The barrel, the middle section of the boiler, is an enclosed cylindrical vessel where water is boiled to produce steam. Heat is supplied through the surface of several small diameter flue tubes which run the entire length of the barrel, and which connect the firebox to the smokebox.

Steam is collected at the top of the barrel and fed through the steam pipe to cylinders, via the superheater (if fitted). The flow of steam is controlled by the regulator valve.

Previous Next

Smoke Box

The smoke box was introduced originally to capture ash and other particles drawn through the tubes. However, its function soon outgrew this simple purpose. The early engineers discovered that by creating a partial vacuum in the smokebox, hot air would be drawn from the fire at an increased rate which in turn increased the rate of steam production. The partial vacuum is created by a device called a blast pipe.

Previous Next

Blast Pipe

The blast pipe is a nozzle at the base of the smoke box through which used steam from the cylinders is exhausted in a high-speed jet. As the steam jet flows out through the chimney, the effect of friction causes the air in the smoke box to be drawn out with it, thereby creating a partial vacuum.

This importance of this effect lies in the way that it links steam generation to steam consumption. As more steam is used the speed of the jet from the blast pipe increases, which in turn increases the vacuum resulting in more hot air being drawn through the tubes from the fire. Not only does this cause more heat to be supplied but the greater air flow through the fire cause it to burn faster.

Previous Next

Control Systems

The driver controls the steam locomotive by adjusting the amount of steam that is used. When the locomotive is running fast or when a lot of power is required to haul a heavy load uphill, considerable quantities of steam are required. The driver controls steam usage by adjusting the regulator. The fireman controls steam production through the rate at which he shovels coal (refuels the fire) and by adjusting the injectors that replenish the water in the bolier.

Previous Next

Regulator

The Regulator is a variable-opening valve in the steam circuit from the bolier to the cylinders. It is adjusted by the driver by means of a lever in the cab. When the regulator is fully open, steam enters the cylinders at full bolier pressure; when it is partially open, steam enters the cylinders at reduced pressure; when it is closed, no steam enters the cylinders.

Previous **Next**

The Engine

The engine part of a steam locomotive is concerned with translating the energy possessed by the steam into motion. However, in order for the locomotive to be useful, sufficient power must be produced to move not only the locomotive but to haul a train.

The steam engine is what is called an external combustion engine. It consists of two of more cylinders and a simple mechanical linkage - the motion - which connects the movement of the pistons (inside the cylinders) directly to the driving wheels.

Previous Next

Cylinders

The cylinders are the heart of the engine. Steam from the boiler is admitted into the cylinders and exerts a pressure on the piston forcing it to move. When the energy in the steam has been given up the used steam is then exhausted into the atmosphere.

Locomotive cylinders are said to be double-acting. In other words, steam is alternately admitted and discharged on both sides of the piston. The admission and discharge of steam is controlled by valves.

Previous Next

Valves

Each cylinder has two valves which operate in a chamber outside the cylinders called a valve chest. However, unlike internal combustion engines, which have separate inlet and exhaust valves, the valves of a steam engine cylinder perform both functions. Moreover, valve timing can be altered by driver to suit power requirements.

The movement of the valves is derived from the movement of the connecting rod through the valve gear.

Previous Next

Valve Timing

In a complete cycle of the piston each of the two valves spend some of the time admitting steam and some of the time releasing used steam. At the start of the stroke the first valve opens to admit steam. When the piston is part of the way down the cylinder the valve closes (the cut-off point) and no more steam is admitted. Just before the piston reaches the end of the stroke the first valve opens to release the used steam and the second valve opens to admit live steam on the other side of the piston. The sequence of events is repeated as the piston returns.

The cut-off point, which is expressed as a percentage of the piston stroke, can be changed by the driver.

Previous | Next

Cut-Off Point

The percentage of the piston stroke during which steam is admitted can be adjusted by the driver to suit power requirements. When power demands are low the driver can set the cut-off to 20% to economise on steam usage; conversely, when power demands are high the driver can increase the cut-off to 70% and obtain maximum power, at the cost of high steam consumption.

Previous

Next

The Motion

The Motion is a generic term for all of the moving parts of a locomotive (except the wheels). These "parts" are concerned with converting the reciprocal movement of the piston into rotation of the wheels.

The piston rod connects the piston to a crosshead which, by virtue of running in a guide, keeps the piston correctly aligned. In turn, a connecting rod connects the crosshead to the crank of the driving wheel. In effect, the connecting rod turns the crank which turns the wheel. A coupling rod transfers the drive to all of the driving wheels.

Previous Next

A Brief History of Locomotive Design

Whilst Richard Trevithick demonstrated the possibilities of steam as a motive power as early as 1805, the age of the steam locomotive truly began with the first public railways in the 1820s. By the 1840s Britain was in the grip of "Railway mania" as the network expanded rapidly and the need for locomotives burgeoned. In the latter years of the 19th century the railways were at their peak, their "Golden Age".

After the First World War, the story is one of continuous retrenchment and decline. Grouping and modernisation, followed by nationalisation after the Second World War and, finally, the end of steam in the 1960s.

Previous Next

The Beginning

The first steam railway was the Stockton and Darlington, which opened in 1825. However, from the point of view of locomotive development, the opening of the Liverpool and Manchester in 1830 was the more significant event.

A competition between aspiring manufactures to provide locomotives was held in 1829. The winner, the immortal "Rocket", proved the viability of the technology. The locomotive that hauled the first train, "Northumbrian", established the definitive form.

Previous Next

Railway Mania

The 1840s saw a rapid expansion in the Railways. All manner of companies sprung up to build railways, everywhere and anywhere. A whole industry came into being to supply the rolling stocke needs.

The steam locomotive had itself become a commodity item, built by numerous manufacturers. Moreover, the Railway companies themselves began building to their own designs to suit their own traffic needs - one design for freight, another for mainline express running and so forth. Some measurement of concensus had been achieved on such important technical issues as to cylinder locations and valve arrangements. And all designers were equally neglectful in providing for safety and comfort of the footplate crew.

Previous   Next

The Golden Age

Towards the end of the 19th century all of the main lines had been built and there was no part of the country that was not served. The numerous Railway companies, great and small, all built their own locomotives and adorned them in highly decorative liveries; the Railway scene would never be quite so colourful again.

The typical locomotive of this era was a simple and conservative beast. Passenger trains were invariably hauled by small 4-4-0s with inside cylinders, slide valves and low-pressure saturated steam boilers; freight by 0-6-0s with similar engine arrangements. Yet even before the 20th century had dawned, it was clear that more powerful designs would be required.

Previous Next

The Need For More Power

In the early days of the Railways standards of passenger comfort left much to be desired. For 2nd and 3rd class passengers, primitive 6-wheeled coaches invariably sufficed. Even with 15 or so such coaches in the train, the load on the locomotive was modest.

Eventually, under pressure from Parliament and their passengers, the Railways were forced to improve comfort and amenities. New coaching stock introduced from the 1890s rode on bogies, had corridors and toilets. It was therefore much heavier. To cope with increase in train weights more powerful and efficient locomotives were required.

Previous Next

The Search for Increased Efficiency

The thermal efficiency of a steam locomotive is notoriously low. The simple, saturated steam locomotives of the late 19th century were reliable but their coal consumption in relation to the work they did was high. In the early years of the 20th century engineers collectively put a great deal of effort into raising efficiency and thus saving on coal.

Efforts were concentrated on improving both steam generation and steam usage. Superheating was found to be most effective in the former case and Compounding in the latter, but whilst superheating became universal, compounding was not widely adopted owing to the extra complexity it introduced into cylinder and valve gear design.

Previous | Next

Saturated Steam

When all of the water droplets in steam have been evaporated it is said to be saturated. For steam at a particular pressure a given amount of heat - the latent heat of evaporation - must be supplied to achieve this condition.

In a locomotive, when saturated steam leaves the boiler it comes into contact with cooler surfaces such as the cylinder walls, and a certain amount of condensation takes place. This condensation removes energy from the steam and results in a significant loss of efficiency.

Previous Next

Superheated Steam

Additional heat can be applied to saturated steam to eliminate the risk of condensation occuring. Raising the temperature beyond the saturation temperature is called superheating.

Superheaters - essentially very long, coiled pipes inside a large flue - were introduced to locomotive boilers from the beginning of the 20th century. They resulted in coal consumption being reduced by as much as 20%.

Previous Next

Compounding

Steam leaving the cylinder still possesses a lot of energy, which is inevitably lost "up the chimney". Compounding was an attempt to reclaim some of this lost energy passing the steam to another cylinder.

In a compound engine, steam from the boiler enters a high pressure cylinder and is then passed to a lower pressure cylinder before being released. This two-stage expansion obtains more work from the steam than a single-stage expansion.

Though significant gains in efficiency were obtained, compounding was not widely adopted because the greater complexity it entailed increased maintenance costs.

Previous | Next

Grouping

After the First World War the numerous small Railway companies were amalgamated into four regional concerns. Naturally, the Big Four (as they were referred to) inherited large fleets of locomotives of various ages and capabilities. Rationalisation was inevitable.

The need for new designs was given extra impetus by the threat, for the first time, of competition from road (and air) transport. The Railways responded by introducing some of the biggest, best and most famous locomotives ever to take to the rails to haul expresses at unprecedented speeds. It wasn't enough to prevent the onset of decline.

Previous Next

Nationalisation and Standardisation

The Railways were nationalised in the aftermath of the Second World War, which left them in a run-down state. Rather than opt for diesel and electric traction, British Railways elected to build new (standard) classes of steam locomotives.

Austerity, simplicity and ease of maintenance were necessarily the hallmarks of the new designs for the new (and financially straitened) age. These traits did indeed help lower running costs but they did nothing to improve the Railway's competitive position against road and air transport.

Previous | Next

The End of Steam

The steam age on British Rail was a long time in dying. The widescale introduction of modern traction began with the 1955 Modernisation Plan, but steam lingered on until 1968.

Many of the locomotives scrapped in the twilight years had managed over 50 years of faithful service, demonstrating the chief virtues of the steam: ruggedness of construction and the ability to continue running under adverse conditions - most locomotives saw out their latter years in a very rundown state.

Previous

C

Programming text

Jackson Structured Programming

This text is about Jackson Structured Programming (JSP) a formal method of program design. The main focus of the text will be on the use of data structure diagrams.

Begin

The Importance Of Software

During the first 3 decades of the computing era, the primary challenge was to develop computer hardware that reduced the cost of processing and storing data. Throughout the decade of the 1980s advances in microelectronics have resulted in more computing power at increasingly low costs.

Today the problem is different. The primary challenge is to reduce the cost and improve the quality of computer based solutions, solutions that are implemented with software.

One way to improve the quality of software and reduce the number of errors occurring in program production is to employ a program design methodology. The focus of this text is to describe such a methodology at a very basic level. The method we will discuss is called Jackson Structured Programming or JSP for short. The text also examines the different requirements of a software methodology and the software lifecycle.

PREVIOUS NEXT

The Software Lifecycle

Software or program production can be separated into five distinct stages: Specification; Design; Implementation; Testing; and Operation and Maintenence.

Each of these stages are important, but successful implementation and operation of a computer program can be enhanced through the application of a rigerous design methodology.

PREVIOUS NEXT

Specification

There must be a detailed specification of the problem, i.e. what the programmer is required to do. It will usually be in written form and will specify the inputs and ouputs to the program and what processing the program will need to do in order to transform the inputs into outputs.

PREVIOUS NEXT

Design

A design must be derived from an analysis of the requiements of the program contained in the specification. The design is usually expressed in some diagrammatic form such as JSP data structures. The level of detail is such that the translation into the programming language is straight forward.

PREVIOUS NEXT

Implementation

The program design must be converted into the chosen programming language and executed on the computer.

PREVIOUS NEXT

Testing

The implmented program must be tested with suitable data to ensure that it meets the requirements of the original program specification, and to check that there are no errors in the source code.

PREVIOUS NEXT

Operation And Maintenence

The program must be installed and used. When errors are discovered they must be corrected. Changes to the program may be required because of changes to the orginal requirements specification.

PREVIOUS NEXT

The Importance Of Design

The importance of properly designed software of any kind cannot be over stressed. In these days when software production and maintenence costs are escalating in relation to total system costs and there is a shortage of skilled software producers, the computing profession can ill-afford to produce substandard software. Yet much poor software is produced, mainly owing to poor problem definition and poor program design.

In response to this problem a number of design methods have been developed. The method we will be talking about is probably the most widely used method of all - Jackson Structured programming. In general all methodologys JSP included have a set of main requirements.

PREVIOUS NEXT

Design Method Requirements

A software design method is a set of basic principles and techniques that enables problems to be solved using a computer. Any design method worth using must have a set of rules to identify the class of problem that can be solved, and to guide the problem solver in a step-by-step manner through the various stages of software production. It must emphasis that the solution of the problem is dependent on the transformation of the input data into results. The outcome of each stage should yield good documentation, allow progress to be assessed, and give early warnings of errors. Essentially there are six main requirements of a design methodology.

PREVIOUS NEXT

Six Main Requirements

1. To enable correct programs to be produced
2. To facilitate the organised control of software projects
3. To facilitate the handling of large and/or complex projects
4. To enable systematic methods to be applied rigorously by trained personnel
5. To provide a method that is "workable" within the intellectual limitations of the average programmer.
6. To afford techniques that can be taught and to not rely on inspiration

PREVIOUS NEXT

Jackson Structured Programming

JSP was first described in 1975 by Michael A. Jackson. The method has evolved over many years and is fully supported by a set of software tools.

Jacksons method views software as a mechanism that transforms input data into an output report, via a set of coherent, synchronized operations. The problem for the designer is to determine what the operations and their sequence ought to be.

Jackson describes his own method has having 4 main characteristics. The method itself can be divided into four basic stages.

PREVIOUS NEXT

The Characteristics Of JSP

Jackson describes his own method as having the following characteristics:

1. It is non-inspirational; it depends little, or not at all, on invention and insight on the part of the designer.
2. It is rational; the design procedure is based on reasoned principles, and each step may be validated in the light of these principles.
3. It is teachable; people can be taught to practise the method and two or more programmers using the method to solve the same problem will arrive at substantially the same solution.
4. It is practical; the method itself is simple and easy to understand, and the designs produced can be implemented without difficulty in any ordinary programming environment.

PREVIOUS NEXT

The Stages Of JSP

The principles of JSP are as follows

1. Analysis of the problem that the program is to solve, and the production of structure diagrams; data are usually the basis of a program, so data structures are created.
2. Analysis of the main programming tasks and the production of a program structure based on the data structures.
3. Definition of the tasks in terms of elementary operations and allocation of each of these to the component parts of the program structure.
4. Conversion of the program structure into a computer programming language.

This text is primarily concerned with the production of data structure diagrams.

PREVIOUS NEXT

The JSP Method

Th first step in the JSP method is to analyse the data to be input to, used by, and out put from the program and to describe its structure using data structure diagrams.

Within JSP the structure of data is analysed and refined into its subsidiary parts (data components) in progressively increasing levels of detail until further refinement is no longer significant.

In this discussion we will describe the three main data components and the focus on the first stage of the JSP method - the production of data structure diagrams.

PREVIOUS NEXT

Data Components

For the vast majority of programs the design will be wholly or mainly dictated by the structure of the input data, which will be organised into one or more files. Files can be broken down into other data componets such as records and items.

PREVIOUS NEXT

Files

The file is the highest level data component, representing a collection of elated data which is to be input to, used by, and output from a program. The data within a file may relate to a particular entity or a set of events.

PREVIOUS NEXT

Records

The record is the next highest level of data components usually associated with data organised into files. A record is a collection of daa rlating to a particular entity or event. E.G. a personel record contains data about an employee

PREVIOUS NEXT

Item

The item or (field) is usually the lowest level of data component associated with files. An item is an attribute of an entity or event. E.G. the name of an employee.

PREVIOUS NEXT

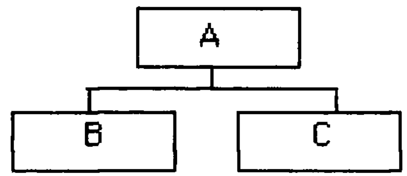
Data Structure Diagrams

Structured program design consists of three constructs commonly used in computer programming. Sequence, Selection, and Iteration. JSP allows us to represent these constructs diagramatically. The purpopse of this approach is to describe data or a problem and the steps needed to solve it. At first it may sems a little daunting, but there are plenty of worked examples to help you.

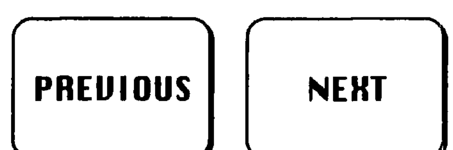
PREVIOUS NEXT

Sequence

The notation for a sequence is shown below:

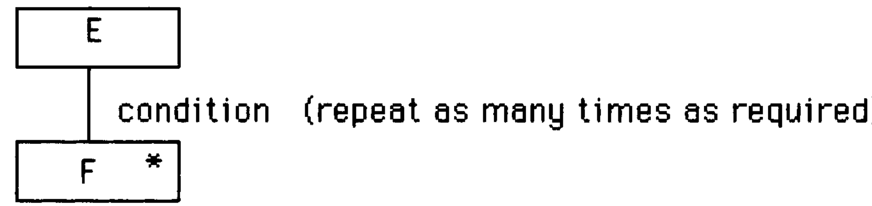


Component (box) A is a sequence. Boxes B and C represent component parts of the sequence. In this case they are not further defined and hence have no structure if their own; they are known as elementary components. In the above example, A is a sequence of two components B followed by C. The notation could of course be extended for a sequence of any number of component parts.Hence this diagram would correspond to the command. Execute B, then C, in that order.



Iteration

The notation for an iteration is shown below

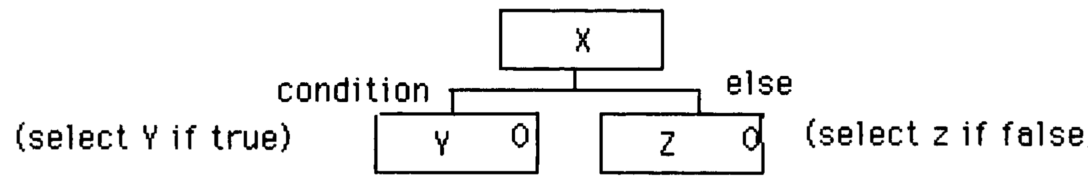


Component (box) E is an iteration. The box F is the iteration component part. E is an iteration of a number of F's. The number of F's is controlled by the specified condition.

PREVIOUS NEXT

Selection

The notation for a selection is shown below:



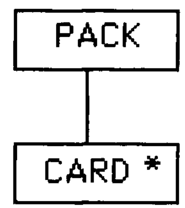
Box X is a selection. Boxes Y and Z are component parts of the selection. In the above example, X is a selection (or choice) of Y or Z. Only the condition for the choice of Y is specified - if this condition is not true Z is chosen. As for a sequence, the notation can be extended for any number of component parts (or choices). The final choice is always goverend by the "else" situation.

PREVIOUS NEXT

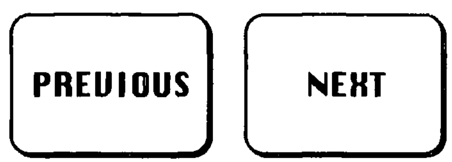
Examples of How Data Structures are Produced

The following examples show how a data structure may be produced from a narrative description using the three constructs, selection, iteration and sequence.

(a)Consider a pack of playing cards as data. If the cards are not sorted the data structure may be represented as follows.



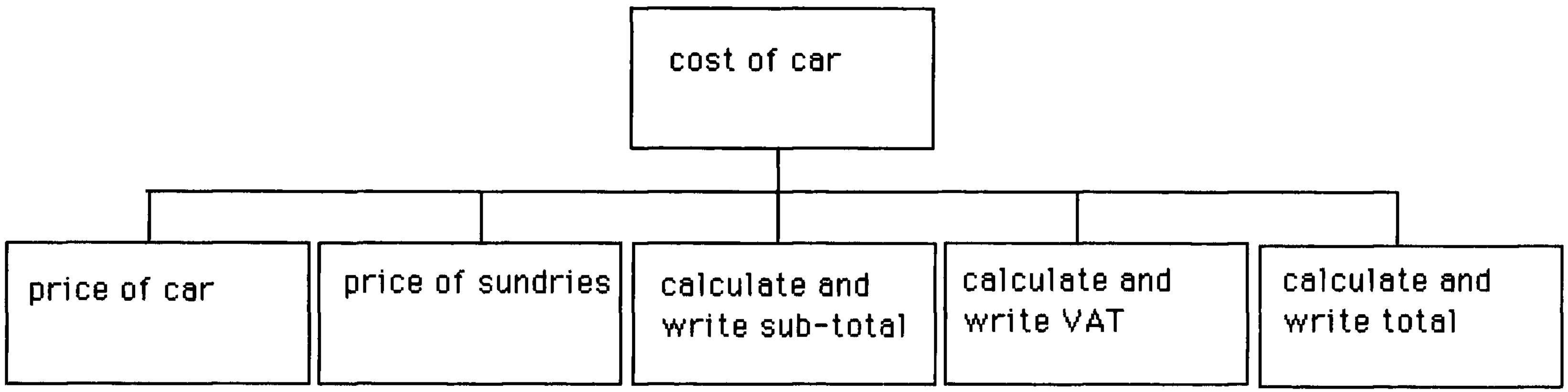
At this stage we do not include conditions on the structure diagram. However, there is no harm in considering what the condition should be. In this case, it is obviously UNTIL END OF PACK



Sequence example one

The following simplified instructions can be used to determine the cost of purchasing a new car.

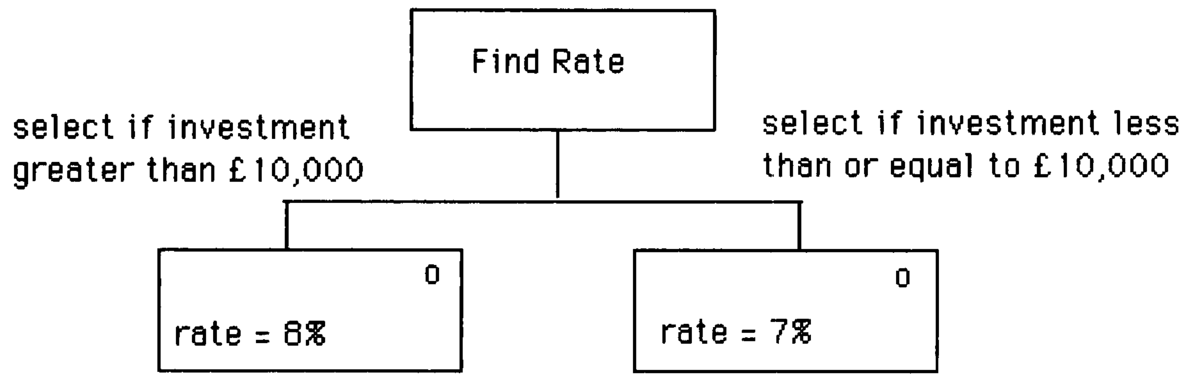
Price of car
Price of sundries (plates, delivery, etc)
Add together these two prices and write down sub-total
Calculate VAT on the sub-total and write down this value
Add together sub-total and results of VAT calculation and write down the total cost of the cars.



PREVIOUS NEXT

Selection example one

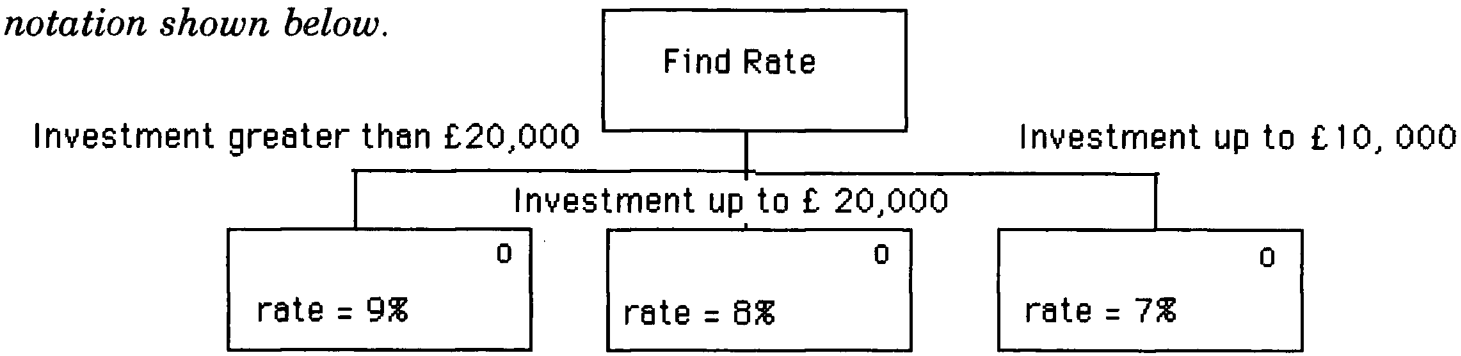
*If a building society pays interest at 7% per annum on investments up to £10,000 and a higher rate of interest at 8% per annum on total investments above £10.000 then the method of selecting the appropriate rate of interest can be represented by the **JSP** notation shown below.*



The notation for a selection is not limited to only a two way selection. See the following example

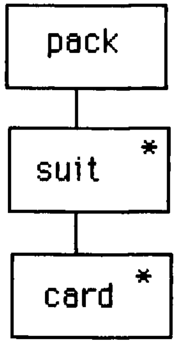
PREVIOUS NEXT

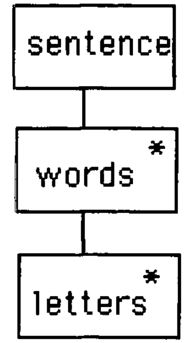
If a building society has three rates of interest based upon different amounts being invested, such that investments up to £10,000 attract 7% per annum, investments exceeding £10,000 and up to £20,000 attract 8% per annum and investments exceeding £20,000 attract the top rate of 9%, then the method for selecting the appropriate rate of interst can be represented by the JSP notation shown below.



PREVIOUS NEXT

A pack of cards is sorted by suit, but the order of the suits is not known. The data structure that represent this situation is shown below



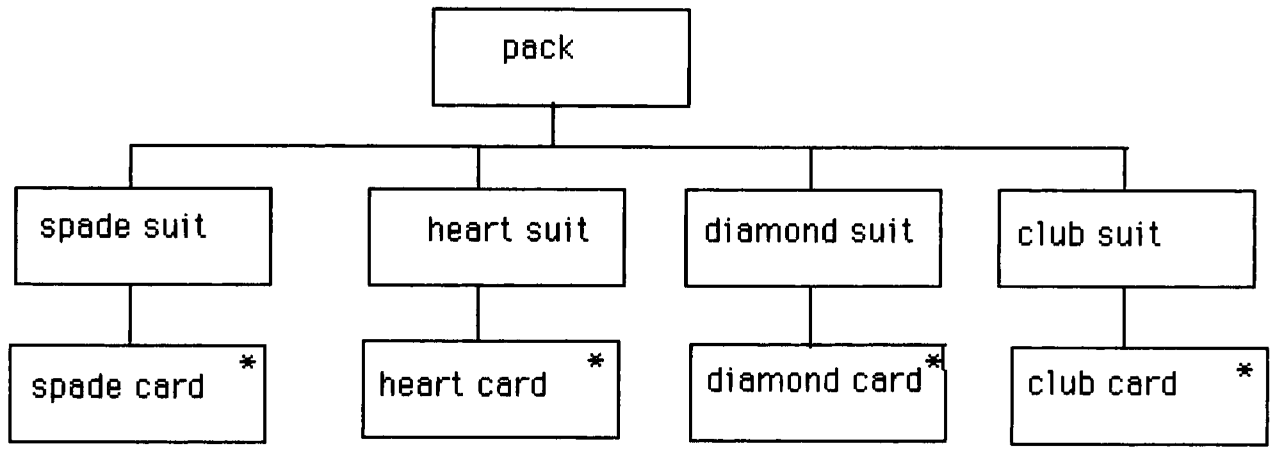


So a pack of cards is comprised of an iteration of suits which in turn is made up of an iteration of cards. Similarily, a sentence is made up of an iteration of words, and words are made up of an iteration of letters.

PREVIOUS NEXT

Structures using more than one construct

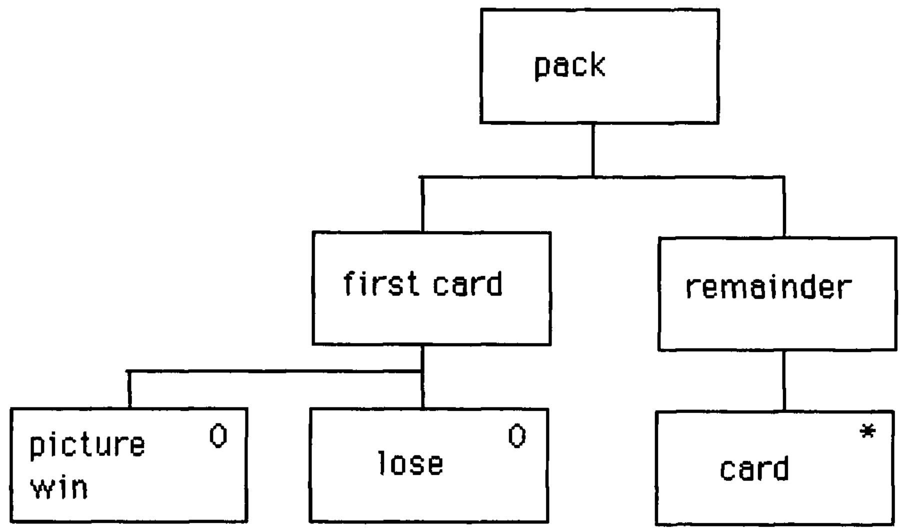
(b) If the pack was sorted by suit, all spades, then the hearts, then the diamonds, then the clubs, we would need to show this division of suits and the sequence of their appearence in the pack. This is shown below:



PREVIOUS NEXT

Mixed Structures Example One

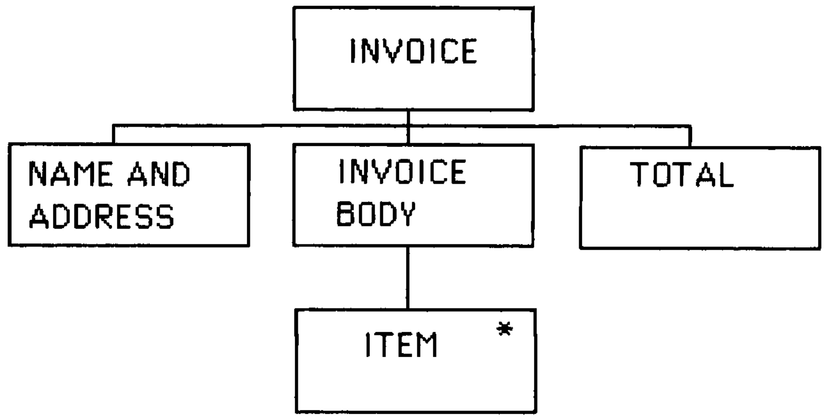
(c) Again, consider a pack of playing cards. Suppose we turn over the first card. If it is a picture cards we win, otherwise we lose. The data structure for the pack is now shown as follows:



PREVIOUS NEXT

Mixed Structures Example Two

An invoice has the customer's name and address at the top and the total amount payable at the bottom. In between there are a number of lines for individual items (we may call this the body of the invoice). The data structure for the invoice is as follows.



PREVIOUS NEXT

D

Navigation Questions

Experiments One and Two

Navigation Questions

Who developed the transfer appropriate processing theory?
Who suggested that the capacity of working memory is seven plus or minus two?
Name two of the component processes of analogical thinking
Name the two types of rehearsal
What is generalisation?
Who studies well defined problems?
What was Baddley's criticism of the Levels of Processing Approach?
What is the capacity of long term memory?
What is means-ends-analysis?
What are semantic constraints?

Five Target Nodes

Structural Constraints
Levels of Processing
Anderson's model of Skill Acquisition
Transfer Appropriate processing
Problem Representation

Experiments Three and Four

Navigation Questions

What is Integration ?
What are semantic constraints ?
What are pragmatic constraints ?
What is elaboration?
What are heuristics?
What is the task environment?
What is problem translation
Who were the information processors?
Who developed the pragmatic theory of analogical thinking?
Who developed the transfer appropriate processing theory?
Who suggested that the capacity of working memory is seven plus or minus two?
Name two of the component processes of analogical thinking
Name the two types of rehearsal
What is generalisation?
Who studies well defined problems?
What was Baddley's criticism of the Levels of Processing Approach?
What is the capacity of long term memory?
What is means-ends-analysis?
What are semantic constraints?
Who developed the Levels of Processing theory?

Experiment Five

Seven Target Nodes

Structural Constraints
Levels of Processing
Scardamalia and Bereiter's Model

Conclusions
The neglect of conceptual understanding
Organisation and clustering
Transfer Appropriate Processing

Experiment Six

Navigation Questions

Who developed the transfer appropriate processing theory?
Who suggested that the capacity of working memory is seven plus or minus two?
Name two of the component processes of analogical thinking
Name the two types of rehearsal
What is generalisation?
Who studies well defined problems?
What was Baddley's criticism of the Levels of Processing Approach?
What is the capacity of long term memory?
What is means-ends-analysis?
What are semantic constraints?

Experiment Nine

Ten Target Nodes

Structural Constraints
Levels of Processing
Scardamalia and Bereiter's Model
Problem Representation
Conclusions
The neglect of conceptual understanding
Organisation and clustering
Analogical Thinking
Transfer Appropriate Processing
Anderson's Model of Skill Acquisition

Experiment 10

Ten Target Nodes - Steam Text

Grouping
Regulator
Blast Pipe
Superheated Steam
The Golden Age
Firebox
Self-propelled Steam Engines
Compounding
Railway Mania
Properties of Steam

Ten Target Nodes - Learning Text

Structural Constraints
Levels of Processing
Scardamalia and Bereiter's Model

Problem Representation
Conclusions
The neglect of conceptual understanding
Organisation and clustering
Analogical Thinking
Transfer Appropriate Processing
Anderson's Model of Skill Acquisition

Experiment Eleven

Ten Target Nodes

Structural Constraints
Levels of Processing
Scardamalia and Bereiter's Model
Problem Representation
Conclusions
The neglect of conceptual understanding
Organisation and clustering
Analogical Thinking
Transfer Appropriate Processing
Anderson's Model of Skill Acquisition

Experiment Twelve

Ten Target Nodes

Structural Constraints
Levels of Processing
Scardamalia and Bereiter's Model
Problem Representation
Conclusions
The neglect of conceptual understanding
Organisation and clustering
Analogical Thinking
Transfer Appropriate Processing
Anderson's Model of Skill Acquisition

E

Learning Questions

EXPERIMENT SEVEN

Factual Questions

Which locomotive hauled the first train?
When was the modernisation plan introduced?
Who built the first stationary steam engine?
The Stockton to Darlington line opened in which year?
Which device causes a partial vacuum to be created in the smokebox?
The Liverpool to Manchester line opened in which year?
The boiler has three distinct parts. Name them.
What is the purpose of the smokebox?
What is the purpose of the boiler?
Name the two separate parts of the steam locomotive.
What is the name of the valve in the steam circuit from the boiler to the cylinders?
Trials were held for the engine design which would finally operate the Liverpool to Manchester line. Where were they held?
In what year were these trials held?
How many years did it take to convert the technology of the stationary steam engine into a self-propelled engine or locomotive?
Superheaters resulted in coal consumption being reduced by how much?
Which decade marked the end of steam?
What is the motion?
What was the maximum speed of Stephenson's Rocket?
Who first demonstrated the possibility of using steam energy for locomotion?
When was the Golden Age of steam?
When were the railways nationalised?
What are superheaters?
When were superheaters introduced?
What decade saw the rapid expansion of the railways
What is the regulator?
What is the firebox?
Where are the flue tubes situated?
What is the barrel?
Where are the control systems located?
What were stationary engines used for?
How many times greater is the volume of steam than the volume of water?
In which year did James Watt adapt the design of stationary engines?
When was the first stationary engine built?
What is the arrangement of the boiler?
How is heat applied to the barrel?
Which valve controls steam flow?
What is the maximum cut off point
How is the cut off point controlled?
What type of engine hauled freight trains
What type of engine hauled passenger trains?

Main Ideas Questions

What is the purpose of the blast pipe and how does it relate to steam consumption?
Describe how the design of steam engines changed to meet the needs of a rapidly expanding network.
How does superheating work?
How does condensation effect efficiency?
How do valves effect the operation of the cylinders in the steam engine?
Which factors were responsible for the decline of steam?
Describe how and why the function of the smoke box has changed

EXPERIMENT EIGHT

Factual Questions

Name the three commonly used programming constructs.
Draw the JSP notation that represents these constructs
Name the three data components
Name one of the characteristics of JSP
What is a design methodology?
Who developed JSP?
In what year was JSP developed?
What are the 5 stages of JSP?
Name one of the 6 requirements of a design methodology
Why is program design so important?

Problem Solving Questions

A customer file is sorted by region code. There are a number of regions in the file and there could be any number of records per region. Draw the data structure of this file.

The same customer file is sorted by credit limit code within region code. Draw the data structure diagram.

In a 'fun run' a majority of the runners completed the course and of these a significant proportion recorded their best time. There was no discrimination between the sexes, but there was two categories of runner -'beginner' and 'past it'. Draw the data structure of all the competitors using the above information. Your solution does not have to reflect the order in which the competitors finished.

A file containing records of students on a three year course is sorted into ascending order of year. A program is required to count the number of second year students who have paid there fees. Draw the data structure for this file.

The standard design for a house includes a specification as follows. The front of the house (looking from left to right) has a large window which may be Georgian style or a picture window, followed by a door which may or may not have a glazed upper section. If the dour has no glazing it may be painted red or green; glazed doors are always green. After the door (on the right hand side of the house) there are either two small windows or a large window. Draw a data structure for the front of the house.

A file contains three different types of records (type 1, type 2, or type 3) Records of type 2 are processed according to region code - if the code is A the record is displayed, otherwise the record is deleted. Draw the data structure of this file.

A PhD thesis consists of a number of chapters within each chapter there are a number of paragraphs. Draw the data structure.

A holiday booking file is sorted by reservations.. There are a number of reservations in the file and there could be any number of records per reservation. Draw the data structure of this file.
A card bought from Frank Butcher's Doggy Deals Car Auction will either be an estate car or a hatchback. If the car is a hatchback it will be supplied with either a CD player or an alarm.

A criminal record file contains information on two types of offence violent and non-violent crime. Draw the data structure of the file

EXPERIMENT NINE

Factual Questions

What is Integration ?
What are semantic constraints ?
What are pragmatic constraints ?
What is elaboration?
What are heuristics?
What is the task environment?
What is problem translation
Who were the information processors?
Who developed the pragmatic theory of analogical thinking?
Who developed the transfer appropriate processing theory?
Who suggested that the capacity of working memory is seven plus or minus two?
Name two of the component processes of analogical thinking
Name the two types of rehearsal
What is generalisation?
Who studies well defined problems?
What was Baddley's criticism of the Levels of Processing Approach?
What is the capacity of long term memory?
What is means-ends-analysis?
What are semantic constraints?
Who developed the Levels of Processing theory?

Main Ideas Questions

Why is understanding the most difficult form of explicit learning?
Explain the theory of transfer appropriate processing
Explain the differences between implicit and explicit learning
Why does semantic processing lead to better memory?
Explain the two way process of learning through understanding
Explain how semantic and structural constraints effect mapping and retrieval of a source analogy
Explain Anderson's model of skill acquisition
The main problem with learning as problem solving is that it can lead t a neglect of understanding. why is this so?
How does memorisation differ from understanding?
Briefly describe Newel and Simon's approach to problem solving
What implications if any does the levels of processing approach have for learning?
What is the role of memory in learning?
Why does problem solving often fail to encourage generalisation ?
Why is rehearsal a poor memory strategy?
What are metacognitive skills and how do they relate to learning as understanding?
In what circumstances should memorisation be used for learning?
Learning as problem solving can lead to a neglect of conceptual understanding. How might this problem be solved?
What is the role of pre-existing knowledge in learning?
Why is generalisation important
Explain the differences between the Information Processors approach to problem solving and that of analogical problem solving.

EXPERIMENT TEN

See questions used in Experiments Seven and Twelve

EXPERIMENT ELEVEN

Factual Questions

What is Integration ?
What are semantic constraints ?
What are pragmatic constraints ?
What is elaboration?
What are heuristics?
What is the task environment?
What is problem translation
Who were the information processors?
Who developed the pragmatic theory of analogical thinking?
Who developed the transfer appropriate processing theory?
Who suggested that the capacity of working memory is seven plus or minus two?
Name two of the component processes of analogical thinking
Name the two types of rehearsal
What is generalisation?
Who studies well defined problems?
What was Baddley's criticism of the Levels of Processing Approach?
What is the capacity of long term memory?
What is means-ends-analysis?
What are semantic constraints?
Who developed the Levels of Processing theory?

EXPERIMENT TWELVE

Factual Questions

What is Integration ?
What are semantic constraints ?
What are pragmatic constraints ?
What is elaboration?
What are heuristics?
What is the task environment?
What is problem translation
Who were the information processors?
Who developed the pragmatic theory of analogical thinking?
Who developed the transfer appropriate processing theory?
Who suggested that the capacity of working memory is seven plus or minus two?
Name the four component processes of analogical thinking *
Name the two types of rehearsal*
What is generalisation?
Who studies well defined problems?
What was Baddley's criticism of the Levels of Processing Approach?
What is the capacity of long term memory?
What is means-ends-analysis?
What are structural constraints?
Who developed the Levels of Processing theory?
What is understanding?
What is memorisation?
What is problem solving/
Name the two types of learning humans engage in?
What is the function of long term memory?
What is the function of working memory?
When is analogical thinking used?
What is the problem space?

How do heuristics differ from algorithms?
According to Newell and Simon what is the most important aspect of the problem solving process?
In analogical thinking when does mapping occur?
In analogical al thinking when does retrieval occur?
Who demonstrated the importance of semantic constraints
Who argues that structural similarity alone will lead to the over generalisation of candidate analogies?
Who suggests that the two most important aspects of understanding are prior knowledge and new material to be learned?
Who Studied the mapping process in analogical thinking?

* Question 12 is worth 4 points and questions 13 is worth two points

Main Ideas Questions

Why is understanding the most difficult form of explicit learning?
Explain the theory of transfer appropriate processing
Explain the differences between implicit and explicit learning
Why does semantic processing lead to better memory?
Explain the two way process of learning through understanding
Explain how semantic and structural constraints effect mapping and retrieval of a source analogy
Explain Anderson's model of skill acquisition
The main problem with learning as problem solving is that it can lead t a neglect of understanding. why is this so?
How does memorisation differ from understanding?
Briefly describe Newel and Simon's approach to problem solving
What implications if any does the levels of processing approach have for learning?
What is the role of memory in learning?
Why does problem solving often fail to encourage generalisation ?
Why is rehearsal a poor memory strategy?
What are metacognitive skills and how do they relate to learning as understanding?
In what circumstances should memorisation be used for learning?
Learning as problem solving can lead to a neglect of conceptual understanding. How might this problem be solved?
What is the role of pre-existing knowledge in learning?
Why is generalisation important
Explain the differences between the Information Processors approach to problem solving and that of analogical problem solving.

F

Anova Tables

EXPERIMENT ONE

Cards Opened During Reading

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	578.0000	289.0000	34.1115	0.0001
Within Groups	9	76.2500	8.4722		
Total	11	654.2500			

Estimate of Document Size

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	3022.2220	1511.1110	4.760	0.0388
Within Groups	9	2854.7427	317.1936		
Total	11	5876.9647			

Additional Cards Questions answering

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	211.3350	105.6675	34.8770	0.0001
Within Groups	9	27.2675	3.0297		
Total	11	238.6025			

Accuracy Questions answering

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	0.000	0.000		
Within Groups	9	0.000	0.000		
Total	11	0.000	0.000		

Time Taken Questions answering

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	1267.2554	633.6277	33.4854	0.0001
Within Groups	9	170.3028	18.9225		
Total	11	1437.5582			

Additional Cards Card Location Task

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	219.0067	109.5033	33.0937	0.0001
Within Groups	9	29.7800	3.3089		
Total	11	248.7867			

Time Taken Card location Task

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	3187.2902	1593.6451	35.0236	0.0001
Within Groups	9	409.5178	45.5020		
Total	11	3596.8080			

EXPERIMENT TWO

Cards Opened During Reading

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	4629.3333	2314.6667	51.1880	0.0000
Within Groups	51	2306.1667	45.2190		
Total	53	6935.5000			

Estimate of Document Size

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	4204.0000	2102.0000	17.1377	0.0000
Within Groups	51	6255.3333	122.6536		
Total	53	10459.3333			

Additional Cards Questions answering

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	421.6878	210.8439	42.1282	0.0000
Within Groups	51	255.2456	5.0048		
Total	53	676.9333			

Accuracy Questions answering

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	56.2593	28.1296	11.7271	0.0001
Within Groups	51	122.3333	2.3987		
Total	53	178.5926			

Time Taken Questions answering

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	9838.4574	4919.2287	55.5398	0.0000
Within Groups	51	4685.8733	91.8799		
Total	53	14524.3308			

Additional Cards Card Location Task

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	343.5378	171.7689	76.4046	0.0000
Within Groups	51	114.6556	2.2481		
Total	53	458.1933			

Time Taken Card location Task

Source	DF	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	2145.7513	1072.8757	43.6115	0.0000
Within Groups	51	1254.6389	24.6008		
Total	53	3400.3902			

EXPERIMENT 3 (CHAPTER 4)

CARDS OPENED during READING

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	2	2828.87	1414.43	62.35
Within groups	27	612.5	22.69	p = .0001
Total	29	3441.37		

REPEATED CARDS

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	2	125.07	62.53	29.94
Within groups	27	56.4	2.09	p = .0001
Total	29	181.47		

TIME

Source	df	Sum of Squares	Mean Square	F-test	P value
Text (A)	2	55148.07	27574.03	25.18	0.0001
sub w.grps	27	29569.85	1095.18		
Repeated Measure (B)	1	1431.4	1431.4	4.99	0.034
AB	2	5299.08	2649.54	9.23	0.0009
B x sub w.grps	27	7752.14	287.12		

ADDITIONAL CARDS

Source	df	Sum of Squares	Mean Square	F-test	P value
Text (A)	2	724.63	362.32	55.69	0.0001
sub w.grps	27	175.65	6.51		
Repeated Measure (B)	1	18.43	18.43	7.45	0.011
AB	2	28.55	14.28	5.77	0.0082
B x sub w.grps	27	66.79	2.47		

CORRECT ANSWERS

Source	df	Sum of Squares	Mean Square	F-test	P value
Text (A)	2	61.3	30.65	26.65	0.0001
sub w.grps	27	31.05	1.15		
Repeated Measure (B)	1	6.02	6.02	2.69	0.1127
AB	2	2.03	1.02	0.45	0.6398
B x sub w.grps	27	60.45	2.24		

EXPERIMENT 4 (CHAPTER 5)

READING

Source	df	Sum of Squares	Mean Square	F-test	P value
Topology (A)	2	1712.07	856.03	84.62	0.0001
Knowl (B)	1	388.8	388.8	38.43	0.0001
AB	2	163.8	81.9	8.1	0.0021
Error	24	242.8	10.12		

REPEATED CARDS

Source	df	Sum of Squares	Mean Square	F-test	P value
Topology (A)	2	51.8	25.9	12.24	0.0002
Knowl (B)	1	24.3	24.3	11.48	0.0024
AB	2	7.8	3.9	1.84	0.1801
Error	24	50.8	2.12		

TIME

Source	df	Sum of Squares	Mean Square	F-test	P value
Topology (A)	2	23986.63	11993.31	24.27	0.0001
Knowl (B)	1	4438.98	4438.98	8.98	0.0062
AB	2	341.7	170.85	0.35	0.7112
sub w. grps	24	11859.83	494.16		
Repeated Measure (C)	1	161.57	161.57	4.68	0.0407
AC	2	1332.09	666.05	19.29	0.0001
BC	1	3.35	3.35	0.1	0.7581
ABC	2	25.4	12.7	0.37	0.696
C x sub w.grps	24	828.54	34.52		

ADDITIONAL CARDS

Source	df	Sum of Squares	Mean Square	F-test	P value
Topology (A)	2	524.16	262.08	39.73	0.0001
Knowl (B)	1	57.78	57.78	8.76	0.0068
AB	2	5.45	2.72	0.41	0.6663
sub w. grps	24	158.33	6.6		
Repeated Measure (C)	1	3.75	3.75	5.68	0.0254
AC	2	23.26	11.63	17.63	0.0001
BC	1	0.02	0.02	0.03	0.8577
ABC	2	1.39	0.69	1.05	0.3647
C x sub w.grps	24	15.83	0.66		

EXPERIMENT 5 (CHAPTER 6)

Direction Pointing

Source	df	Sum of Squares	Mean Square	F-test	P value
Training condition (A)	1	24	24	23.61	0.0001
Knowl (B)	1	0	0	0	1
AB	1	0.17	0.17	0.16	0.6899
Error	20	20.33	1.02		

Distance Estimation

Source	df	Sum of Squares	Mean Square	F-test	P value
Training condition (A)	1	30.15	30.15	28.64	0.0001
Knowl (B)	1	12.76	12.76	12.12	0.0024
AB	1	7.82	7.82	7.43	0.013
Error	20	21.025	1.05		

Additional Cards

Source	df	Sum of Squares	Mean Square	F-test	P value
Training condition (A)	1	56.7	56.7	60.08	0.0001
Knowl (B)	1	11.94	11.94	12.65	0.002
AB	1	6.86	6.86	7.27	0.0139
Error	20	18.88	0.94		

Cognitive map

Source	df	Sum of Squares	Mean Square	F-test	P value
Training condition (A)	1	852.042	852.042	36.529	0.0001
Knowl (B)	1	0.042	0.042	0.002	0.9667
AB	1	0.375	0.375	0.016	0.9004
Error	20	466.500	23.325		

EXPERIMENT 6 (CHAPTER 6)

Cards opened during browsing

Source	df	Sum of Squares	Mean Square	F-test	P value
Aid (A)	2	2688.389	1344.194	60.024	0.0001
Knowl (B)	1	250.694	250.694	11.194	0.0022
AB	2	53.389	26.694	1.192	.3176
Error	30	671.83	22.394		

Repeated cards

Source	df	Sum of Squares	Mean Square	F-test	P value
Aid (A)	2	75.056	37.528	17.591	0.0001
Knowl (B)	1	13.444	13.444	6.302	0.0177
AB	2	2.722	1.361	0.638	0.5354
Error	30	64	2.133		

CORRECT ANSWERS

Source	df	Sum of Squares	Mean Square	F-test	P value
Aid (A)	2	26	13	19.664	0.0001
Knowl (B)	1	23.361	23.361	35.336	0.0001
AB	2	17.556	8.776	13.277	0.0001
Error	30	19.833	0.661		

TIME

Source	df	Sum of Squares	Mean Square	F-test	P value
Aid (A)	2	3461.36	3461.36	20.29	0.0001
Knowl (B)	1	8566.17	4283.08	25.11	0.0001
AB	2	1358.39	679.19	3.98	0.0293
Error	30	5116.83	170.56		

Additional Cards

Source	df	Sum of Squares	Mean Square	F-test	P value
Aid (A)	2	49.21	49.21	23.27	0.0001
Knowl (B)	1	212.73	106.37	50.29	0.0001
AB	2	17.82	8.91	4.21	0.0244
Error	30	63.45	2.12		

Cognitive Map

Source	df	Sum of Squares	Mean Square	F-test	P value
Aid (A)	2	1189.5	594.75	50.91	0.0001
Knowl (B)	1	210.25	210.25	18	0.0002
AB	2	94.5	47.25	4.04	0.0279
Error	30	350.5	11.68		

AID USE

Source	df	Sum of Squares	Mean Square	F-test	P value
Aid (A)	1	36.75	36.75	19.26	0.0003
Knowl (B)	1	300	300	157.21	0.0001
AB	1	12	12	6.29	0.0209
sub w. grps	20	38.17	1.91		
Repeated Measure (C)	1	70.08	70.08	10.8	0.0037
AC	1	24.08	24.08	3.71	0.0684
BC	1	3	3	0.46	0.5044
ABC	1	12	12	1.85	0.1891
C x sub w.grps	20	129.83	6.49		

QUESTIONNAIRE

Source	df	Sum of Squares	Mean Square	F-test	P value
Aid (A)	2	1384.67	692.33	29.38	0.0001
Knowl (B)	1	544.44	544.44	23.1	0.0001
AB	2	62.89	31.44	1.33	0.2785
Error	30	707	23.57		

EXPERIMENT 8 (CHAPTER 7)

Factual Questions

Source	df	Sum of Squares	Mean Square	F-test	P value
Text (A)	1	36.75	36.75	6.96	0.015
sub w.grps	22	116.167	116.167		
Repeated Measure (B)	1	176.333	176.333	76.566	0.0001
AB	1	12	12	5.211	0.0325
B x sub w.grps	22	50.667	2.303		

Problem Solving Questions

Source	df	Sum of Squares	Mean Square	F-test	P value
Text (A)	1	33.333	33.333	1.592	0.2202
sub w.grps	22	460.583	20.936		
Repeated Measure (B)	1	243	243	64.474	0.0001
AB	1	70.083	70.083	18.595	0.0003
B x sub w.grps	22	82.917	3.769		

EXPERIMENT 9 (CHAPTER 7)

Time Spent Reading

Source	df	Sum of Squares	Mean Square	F-test	P value
Text (A)	1	5.281	5.281	0.308	0.5835
Knowl (B)	1	42.781	42.781	2.492	0.1256
AB	1	52.531	52.531	3.06	0.0912
Error	28	480.652	17.165		

Time Taken (Search Task)

Source	df	Sum of Squares	Mean Square	F-test	P value
Text (A)	1	3526.95	3526.95	48.959	0.0001
Knowl (B)	1	2511.101	2511.101	34.858	0.0001
AB	1	1085.897	1085.897	15.074	0.0006
Error	28	2017.083	72.039		

Additional cards

Source	df	Sum of Squares	Mean Square	F-test	P value
Text (A)	1	83.205	83.205	67.824	0.0001
Knowl (B)	1	19.845	19.845	16.176	0.0004
AB	1	5.12	5.12	4.174	0.0506
Error	28	34.35	1.227		

Answers to Factual Questions

Source	df	Sum of Squares	Mean Square	F-test	P value
Text (A)	1	2.25	2.25	0.573	0.4552
Knowl (B)	1	232.562	232.562	59.265	0.0001
AB	1	18.062	18.062	4.603	0.0407
sub w. grps	28	109.875	3.924		
Repeated Measure (C)	1	256	256	81.57	0.0001
AC	1	0	0	0	1
BC	1	10.562	10.562	3.366	0.0772
ABC	1	0.562	0.562	0.179	0.6753
C x sub w.grps	28	87.875	3.138		

Main Ideas questions

Source	df	Sum of Squares	Mean Square	F-test	P value
Text (A)	1	0.563	0.563	0.197	0.6604
Knowl (B)	1	552.250	552.250	193.590	0.0000
AB	1	105.063	105.063	36.829	0.0000
sub w. grps	28	79.875	2.853		
Repeated Measure (C)	1	132.250	132.250	163.668	0.0000
AC	1	10.563	10.563	13.072	0.0012
BC	1	1.000	1.000	1.238	0.2754
ABC	1	1.563	1.563	1.934	0.1753
C x sub w.grps	28	22.625	0.808		

EXPERIMENT 10 (CHAPTER 8)

Time Reading

Source	df	Sum of Squares	Mean Square	F-test	P value
Within+Residual	18	192.25	10.68		
Topic	1	18.22	18.22	1.71	0.208
Within+Residual	18	341.85	18.99		
Text	1	30.62	30.62	1.61	0.220
Text by Topic	1	24.02	24.02	1.27	0.275

Additional cards

Source	df	Sum of Squares	Mean Square	F-test	P value
Within+Residual	18	42.05	2.34		
Topic	1	7.22	7.22	3.09	0.096
Within+Residual	18	54.85	3.05		
Text	1	140.63	140.63	46.15	0.000
Text by Topic	1	9.02	9.02	2.96	0.102

Time taken (search task)

Source	df	Sum of Squares	Mean Square	F-test	P value
Within+Residual	18	3364.62	186.92		
Topic	1	74.72	74.72	0.40	0.535
Within+Residual	18	1784.86	99.16		
Text	1	4820.00	4820.00	48.61	0.000
Text by Topic	1	196.91	196.91	1.99	0.176

Factual Questions

Source	df	Sum of Squares	Mean Square	F-test	P value
Topic (A)	1	6.613	6.613	1.106	0.3069
Error	18	107.625	5.979		
Organisation (B)	1	6.612	6.612	4.954	0.0390
AB	1	3.613	3.613	2.707	0.1173
Error	18	24.025	1.335		
Phase (C)	1	177.013	177.013	137.189	0.0000
AC	1	0.013	0.013	0.010	0.9227
Error	18	23.225	1.290		
BC	1	37.813	37.813	23.945	0.0001
ABC	1	1.013	1.013	0.641	0.4337
Error	18	28.425	1.597		

Main Idea Questions

Source	df	Sum of Squares	Mean Square	F-test	P value
Topic (A)	1	7.200	7.200	2.323	0.1449
Error	18	55.800	3.100		
Organisation (B)	1	0.800	0.800	0.356	0.5579
AB	1	0.800	0.800	0.356	0.5579
Error	18	40.400	2.244		
Phase (C)	1	168.200	168.200	91.475	0.0000
AC	1	1.800	1.800	0.982	0.3349
Error	18	33.000	1.833		
BC	1	16.200	16.200	12.150	0.0026
ABC	1	1.800	1.800	1.350	0.2605
Error	18	24.000	1.333		

EXPERIMENT 11 (CHAPTER 9)

Time Spent Reading

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	2	26.722	13.361	.585
Within groups	33	754.167	22.854	p = .563
Total	35	780.889		

Time Taken (Search Task)

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	2	7907.618	3953.809	23.838
Within groups	33	5473.522	165.864	p = .0001
Total	35	13381.14		

Additional Cards (Search Task)

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	2	161.194	80.597	107.426
Within groups	33	24.758	.75	p = .0001
Total	35	185.952		

Correct Answers

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	2	15.167	7.583	.708
Within groups	33	353.583	10.715	p = .5001
Total	35	368.75		

Recalled Node Titles

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	2	413.389	206.694	6.893
Within groups	33	989.5	29.985	p = .0032
Total	35	1402.889		

EXPERIMENT 12 (CHAPTER 9)

Time Spent Reading

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	2	27.467	13.733	.605
Within groups	27	613.2	22.711	p = .5535
Total	29	640.667		

Time Taken (Search Task)

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	2	9024.024	4512.012	15.446
Within groups	27	7887.174	292.118	p = .0001
Total	29	16911.198		

Additional Cards (Search Task)

Analysis of Variance Table

Source:	DF:	Sum Squares:	Mean Square:	F-test:
Between groups	2	254.204	127.102	56.809
Within groups	27	60.408	2.237	p = .0001
Total	29	314.613		

Factual Questions

Source	df	Sum of Squares	Mean Square	F-test	P value
Aid (A)	2	34.633	17.317	5.307	0.0114
sub w.groups	27	88.1	3.263		
Repeated Measure (B)	1	123.267	123.267	99.946	0.0001
AB	2	39.433	19.717	15.986	0.0001
B x sub w.groups	27	33.3	1.233		

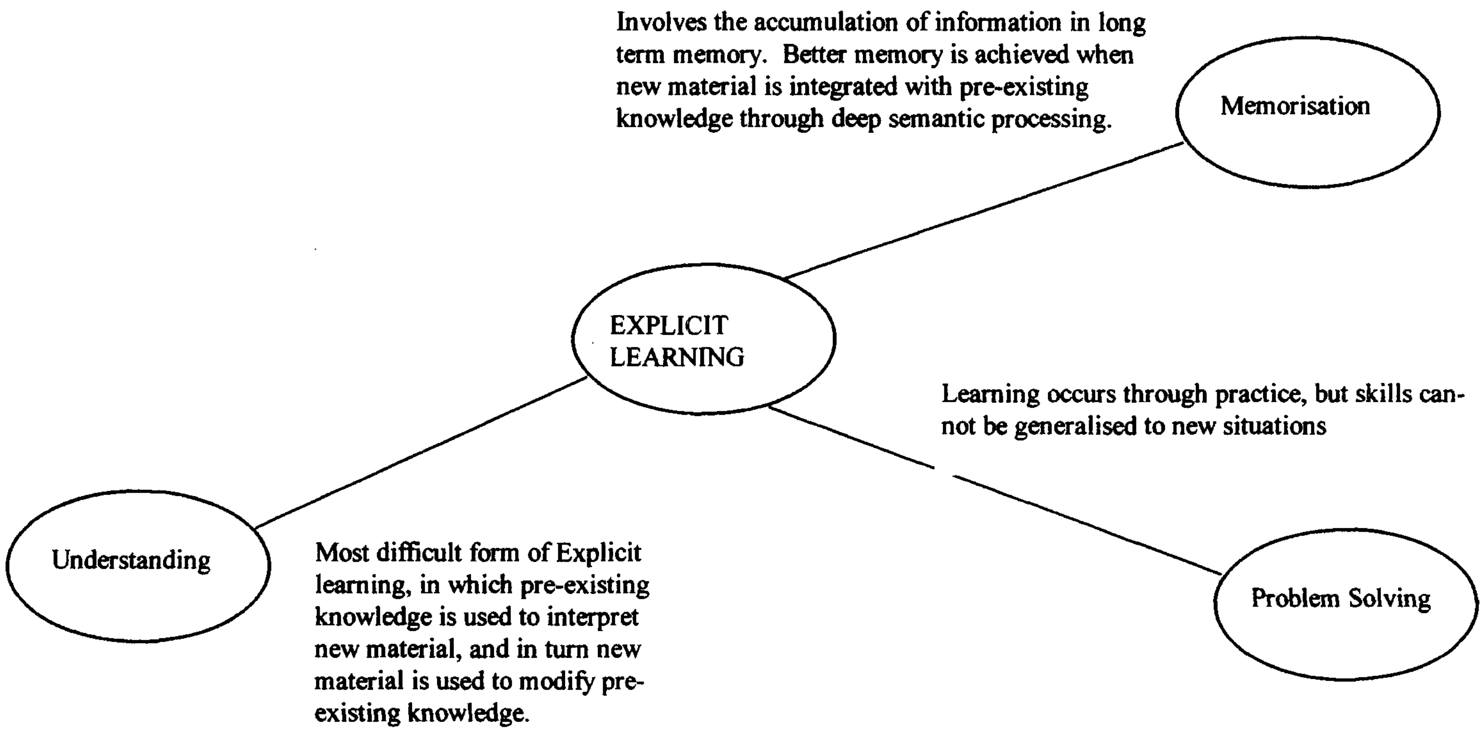
Main Ideas Questions

Source	df	Sum of Squares	Mean Square	F-test	P value
Aid (A)	2	340.433	170.217	16.943	0.0001
sub w.groups	27	271.25	10.046		
Repeated Measure (B)	1	114.817	114.817	76.639	0.001
AB	2	21.233	10.617	7.087	0.0034
B x sub w.groups	27	40.45	1.498		

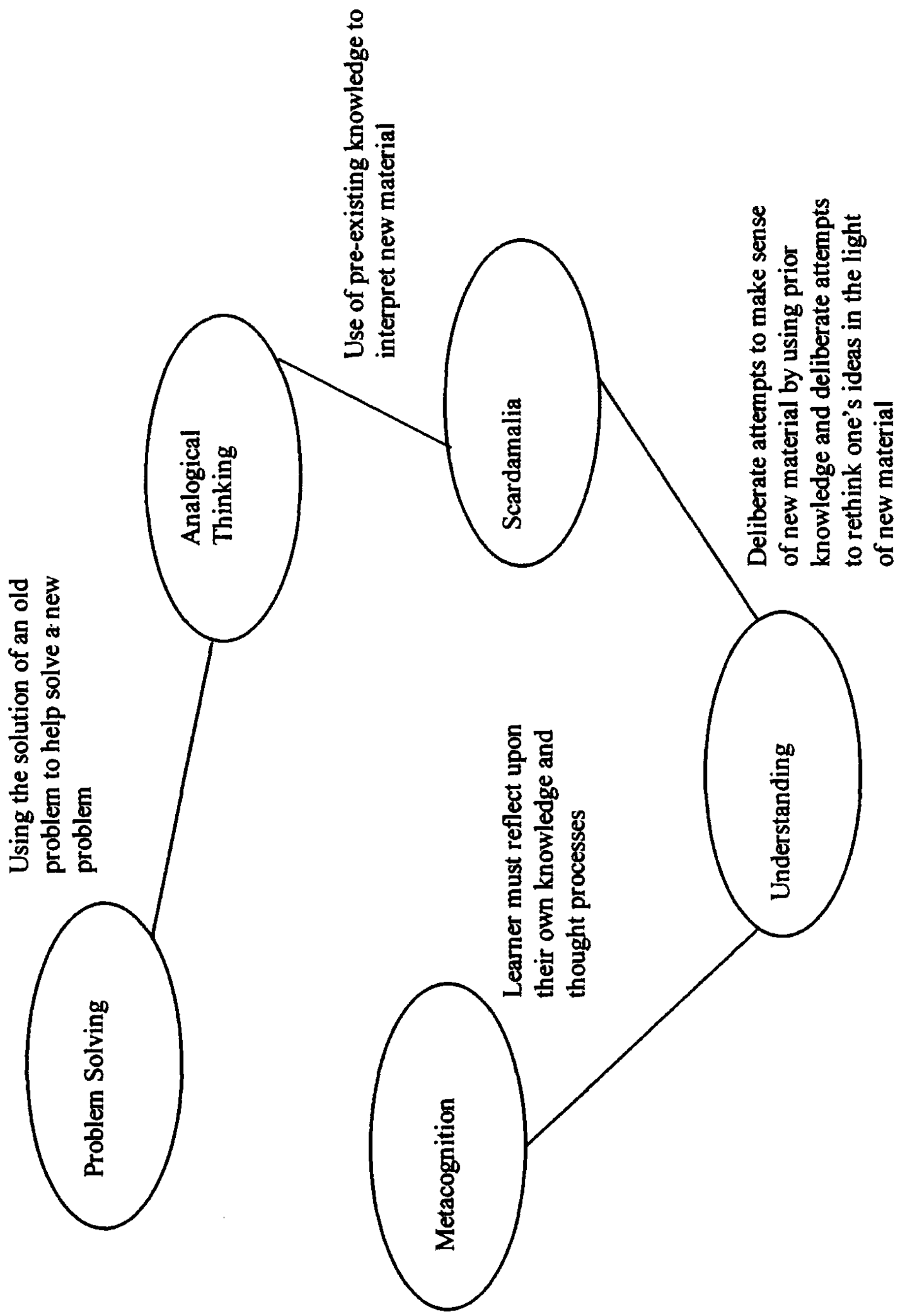
G

Conceptual Maps

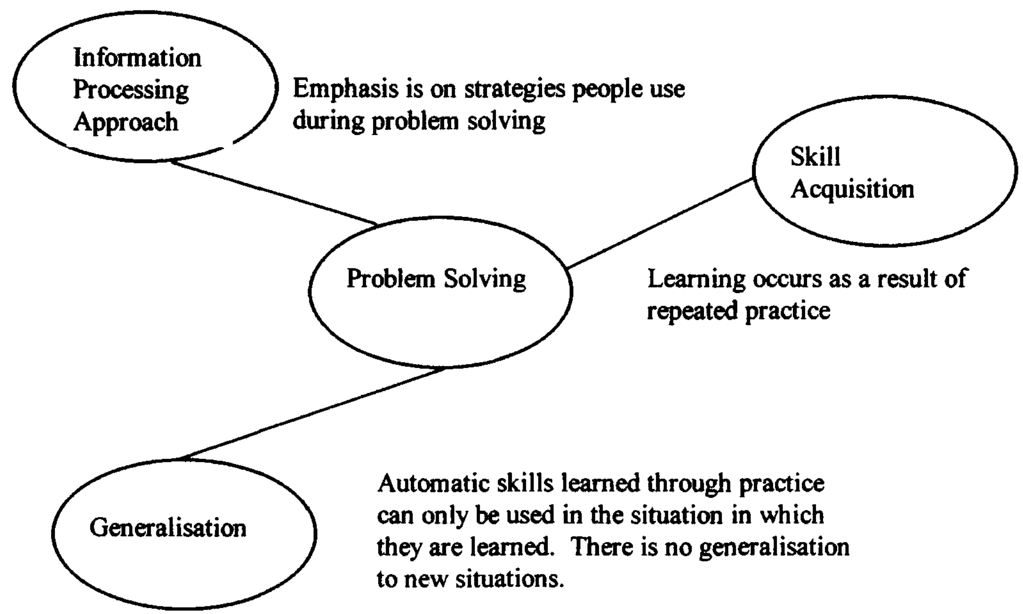
Overview Map



Understanding



Problem Solving



Memorisation