

**Evaluating book and hypertext: analysis of individual differences**

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## Abstract

This thesis investigates the usability of an 800 page textbook compared with a hypertext version containing the same information. Hypertext is an interesting new medium in that it is seen as possessing advantages as both *delivery technology* that influence cost and access to information and *design technology* influencing student achievement. Unfortunately the proclamations of its advocates have usually exceeded empirical findings. Also, rapid advances in both hardware and software are necessitating the frequent re-evaluation of contemporary hypertext.

In addition to an up-to-date evaluation of the relative performance of book and hypertext supporting set tasks, the research reported in this thesis also sought to specifically analyse the potential role individual differences could play within media evaluation. To do this the cognitive styles and spatial ability of 57 postgraduate student volunteers, from two computer related diplomas, were measured. Half the subjects were then randomly assigned to a Book group and half to a Hypertext group. Each group was then allocated the same amount of time to complete two separate tasks: 1) short answer questions analysing the basic information retrieval potential of each medium, and one week later 2) four open-ended short essay questions. Surprisingly, subjects assigned to the Book group performed significantly better than those assigned to the Hypertext group for Task 1. The mean academic performance of subjects (the mean mark obtained over the 8 modules of their diploma) predicted most variance in Task 1 performance for both groups. However, with Task 2, the cognitively more demanding exercise, none of the measured individual differences could significantly predict the scores of subjects. Another surprising finding, given that all subjects were studying computing, was that the amount of prior computing experience was found to approach significance for those subjects assigned to Hypertext for Task 1. Given the ease with which this particular individual difference could be manipulated it was decided to run a second experiment employing subjects with more experience of the Hypertext system used. The results from this second cohort showed no significant differences in score for either task between Book or Hypertext. However, as the more qualitative data from a questionnaire showed, there are a large number of different factors and issues that contribute to the ultimate acceptability of one medium compared with the other.

The thesis concludes by recommending a number of possible avenues for future research looking at the role hypertext has to play in the construction of hyperlibraries and Virtual Learning Environments.

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# 1. Introduction

This thesis primarily discusses research conducted by the author at Napier University. A number of the themes emerging from this research have also been influenced by the experiences and practices encountered by the author while working on the Networked Learning Environment (NLE) project at the University of Nottingham.

## 1.1 Motivation for the Research

Interest in new forms of computer-based/supported forms of education has exploded in recent years. There can be few, if any, UK higher education departments that have not at least considered possible implementation strategies for computer-based curriculum support. Although there is a large amount of interest in electronic forms of education, corresponding guidance from the research community does not seem to be satisfying this thirst for knowledge. Jacobson and Spiro (1995, p. 301) assert:

“Although the use of hypertext systems for learning complex knowledge has been attracting recent attention, we currently have poor theoretical and research perspectives from which to understand the special characteristics associated with learning in nonlinear and multidimensional hypertext instructional systems.”

Similar sentiments were expressed by Ayersman (1996) one year later:

“Although much has been written about hypermedia-based learning, very little of the writing has been research based. Much of the available literature on hypermedia consists of predictive views of hypermedia's potential, descriptive essays explaining various hypermedia systems, and narrative tomes opining reasons why hypermedia is an effective tool for teaching and learning. The majority of this literature is generally more promotional than investigative.”

More recently, Lowe and Hall (1999) go as far as suggesting that hypermedia might be about to suffer a crisis. They argue: "There is little understanding of development methodologies, measurement and evaluation techniques, development processes, application quality and project management." (Lowe & Hall, 1999, p 14). Another problem affecting the field of educational technology is the short shelf-life of some of the published research. For example, Riding and Chambers (1992) report in their paper that a CD-ROM they used did not contain the diagrams and illustrations that were available in the paper textbook. Almost ten years later and not only would it be unthinkable not to digitise the images, but several systems are actually going beyond what can be achieved with paper (e.g. audio, video and animation). However, in spite of the many problems facing the field, there are thousands of educational web sites that have already been in existence for a number of years. If there is such a lack of knowledge about the processes of hypertext creation and use, why then have so many departments and institutions already taken the risk of using these new, and often unproven, technologies? To fully answer this question it is first necessary to understand the growing pressures which are driving the higher education community towards these uncharted technological waters.

One of the most important issues facing higher education during the last few decades has been growing economic pressure. In the period between 1970 and 1996 the number of students enrolled in higher education increased three-fold (Matheson & Pullinger, 1999). However, the amount spent on education expressed as a percentage of GDP has remained almost exactly the same. During the same period the cost of books and journals increased much faster than inflation. The period from 1986 to 1997 alone saw a 308% increase in the cost of UK serials (Mosher, 1995). The issue is further complicated by the nature of some of the rapidly changing domains such as computing. Whereas traditionally a library could purchase titles for use over ten or twenty years, nowadays librarians have to annually (or even more frequently) review their acquisitions on a particular subject matter.

Accountability is another factor which has been given a higher priority recently. New methods are required to audit curricula in preparation for Quality Assurance Assessment (QAA) reviews and internal committee scrutinisation. Some fields, for example medicine, also have to report to professional bodies such as the General Medical Council to ensure educational quality is maintained. What can be thought of as a simple task, ascertaining just what is taught, can be difficult without computer support in the auditing process, especially in large, multi-school subject domains.

Even if the above problems of rising student numbers, growing publication charges and accountability are solved, simple access to information is not guaranteed to always create the desired learning effect. Frequently large differences in performance, as measured by various forms of assessment, can be found in individuals in the same class given the same instruction by the same methods (Riding & Sadler-Smith, 1992; Dählback, Höök & Sjölander, 1996). Advances within cognitive psychology have developed new theories to describe the processes by which individuals handle information in an attempt to resolve these differences in performance. In addition to the well known broad constructs of intelligence and personality, research has uncovered evidence of a third important dimension labelled cognitive style. Unlike 'intelligence' which describes *what* information is being processed (e.g. linguistic, mathematical, spatial), cognitive style refers to *how* this information is processed. Each style is expressed as a bipolar continuum, for example verbaliser-imager or wholist-analytic. There is some evidence that if the learning material does not suit the innate style of an individual then they can to some extent transform the material into a format that is more suitable. However, Riding and Agrell (1997) found that individuals with less intelligence found this transformation more difficult. Given the rapid expansion of higher education over the last thirty years, appreciation of various cognitive differences is essential if all learners are to reach their full potential. Research again is investigating the application of IT to the improvement of teaching and learning. Some experts favour the development of different instructional versions to *match* each cognitive style (Andris, 1996; Riding & Sadler-Smith, 1992). Others, however, take the opposite position and recommend developing instruction to deliberately *mismatch* style to

encourage flexibility in cognitive processing and hopefully deeper learning (Mayes, Kibby & Anderson, 1990b; Presland, 1994).

The keystone of these problems appears to be information. Affordable information from an economic perspective, quality information from an auditing perspective and appropriately structured/formatted information from a cognitive psychology perspective. These underlying information needs have existed in education for a very long time. What is new is educators' interest in the use of new technologies, like hypertext/hypermedia, to act as tools with which to create, maintain, transmit and otherwise utilise information. The ability to manage information effectively has been covered by many influential writers, most notably Bush (1945) and Ted Nelson in the 1960's. More recently Robertson (1998) has even argued that key levels of civilisation (pre-language, language, writing, printing and computers) could not achieve certain things because they lacked the necessary infrastructure to process the quantities of information necessary. While it is not possible within the scope of a research project to evaluate the suitability of various media in the support of the growing information needs of civilisation, it is, however, possible to evaluate specific media within more local contexts. It is the aim of this thesis to focus on the use of hypertext as a computer-based medium supporting a multi-disciplinary knowledge domain at post-graduate level.

## 1.2 Aims of the Research

*What is the usability of a modern hypertext system compared with a paper-based book covering the same multi-disciplinary knowledge domain?*

Lowe and Hall (1999) assert that *usability* is likely to be the most evident characteristic of a hypertext system that determines whether the system can achieve its goals. They continue by stating "This tells us that for an application to be usable it needs to 'facilitate access to, and manipulation of' information." (Lowe and Hall, 1999, p. 138). Although a wide variety of different hypertext projects have already been reported in the

literature, prolific developments within both the hypertext field and more generally in computing, necessitate a frequent re-evaluation of the current state-of-the-art. As such, this thesis seeks to compare the relative usability of a modern hypertext system with a paper-based book supporting the domain of Human-Computer Interaction.

***Do individual differences have a role to play in evaluation methodology even when the systems have not been explicitly designed to match/mismatch these differences?***

Within this overarching aim, the research sought to investigate the utility of certain individual differences variables in media evaluation. Research, mainly from cognitive psychology, has repeatedly demonstrated that significant differences in the performance of users can be found when the instructional condition is manipulated to either match or mismatch the individual differences being investigated. However, it is argued in this thesis that two primary factors limit the wider applicability of this aptitude-treatment interaction research. Firstly, given the increasing higher education student population and unmatched financial support, it is increasingly unlikely that lecturers will have either the time, inclination or the funding to create multiple forms of their teaching materials for various student 'styles'. Secondly, some of the research appears to have manipulated the instructional treatments to emphasise and reveal various theoretical constructs, such as different intelligences or cognitive styles, whereas 'typical' educational material might not have such extreme reactions to the styles being investigated. Thus, a goal of the current research was to investigate the relationship between selected individual differences and un-modified educational treatments that are directly relevant to real-world use.

***How important are training and familiarisation with hypertext when performing set tasks?***

The results from a set of experiments (see Chapter 7), conducted by the author, designed to answer the above two questions indicated the possible importance of hypertext familiarity. Books are used almost effortlessly by higher education students. However, such abilities have been learnt, practised and refined over many years of school-based

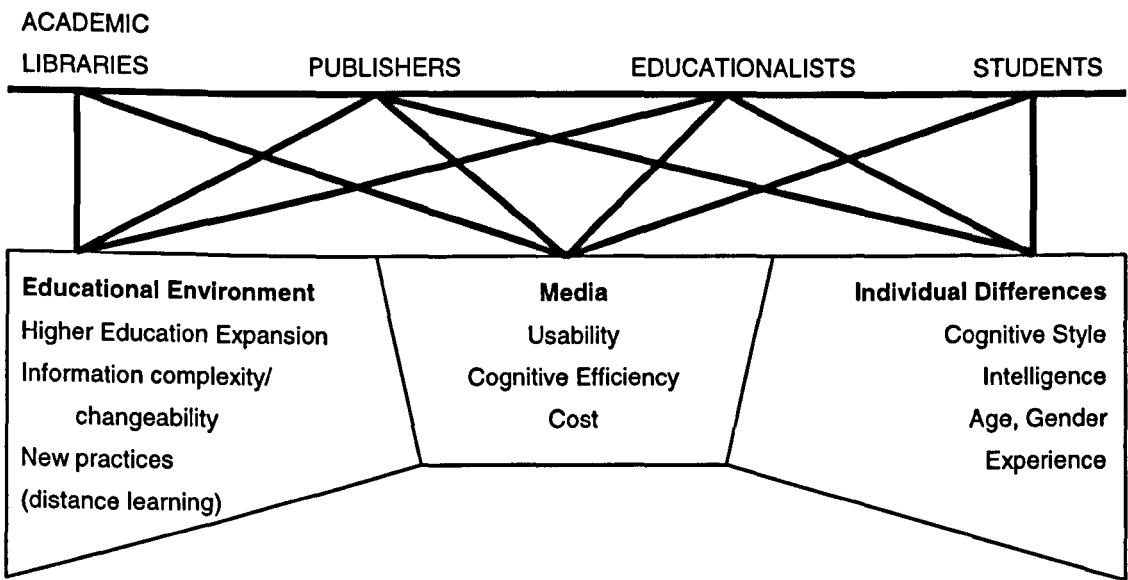
education. The majority of individuals, whether in higher education or not, do not currently have as much experience reading and manipulating electronic documents as they do with print-based materials. Thus, a third question which the current research sought to address was what effect does additional training and familiarisation have on hypertext performance? The results of a second set of experiments, employing the same hypertext and topic as the first experiment, is reported in Chapter 8. Previous research has shown that some hypertext systems have demonstrable advantages over alternative media, while other studies reveal the opposite situation. In the case of the 'failed' hypertext studies, it is sometimes difficult to tell whether it was the hypertext user interface which was inappropriate, the knowledge domain represented, or whether the hypertext familiarity of the subjects used was less than their familiarity with the other experimental media. Although the current research would not be able to provide *post hoc* analysis of such previous work, it would be able to contribute to the likely importance of hypertext familiarity. This information could then be used to improve the design of future media studies.

***What is the best method of hypertextualising existing information sources and what are the issues involved?***

The processes surrounding hypertext creation and possible prior translation from alternative information formats is a very large field and one that cannot adequately be addressed by a single thesis. However, it is the intention of the current thesis to contribute a single case study example illustrating one possible translation process from paper-based book to desktop hypertext system. Although of limited applicability on its own, taken with other translation projects and those hypertexts created from scratch, this thesis hopes to contribute to the field's growing knowledge about what type of hypertext works in particular situations and what is the best way to construct such a system.

### 1.3 Structure of the Thesis

Following the brief introduction above, the next three chapters review previous literature relevant to the research. Three main fields appear most relevant, as shown by the supporting blocks in Figure 1.1: educational environment, media and individual differences. Chapter 2 begins by outlining some of the changes that are fundamentally affecting the higher education landscape: from rapidly changing information to increased student numbers and the need to make education more efficient. Continuing the theme of efficacy, Chapter 3 explores some of the important individual differences from a educational psychology perspective in an attempt to explore why large variations in learner performance can often be observed in the same situation (e.g. an exam, practical, tutorial). Chapter 4 then turns to a discussion of media and, in more detail, hypertext, one of the more recent media to be used in higher education. It is argued in this thesis that it is media, as depicted by the keystone in Figure 1.1, where the fields of higher education and individual differences research intersect. Along the top of the 'handrail' can be seen the main stakeholders of interest to the current research ranging from academic libraries and publishers to educationalists and students. The spars supporting the handrail symbolically illustrate the main interests between the three main fields of educational environment, media and individual differences and the main stakeholders.



**Figure 1.1** Overview of scope of the research: principal stakeholders (capitalised), main themes (emboldened) and key issues (listed).

Using this tripartite discussion as a basis, Chapter 5 presents the research methodology. The reasons behind the chosen methodology are explained together with the research hypotheses and subject matter selected for the evaluation. Using this subject matter, Chapter 6 explains how an 800 page book was converted into hypertext form – what structure was chosen, how each chapter was ‘chunked’ into nodes, and how links were identified and implemented. In addition to the actual conversion process, this chapter also covers some of the design decisions unique to the online medium.

An initial set of experiments designed to investigate the research aims and hypotheses is presented in Chapter 7. Two independent groups of subjects were used, one assigned to a Book condition and the other to a Hypertext condition. Following the measurement of certain individual differences, such as field-dependence (Group Embedded Figures Test), wholist-analytic processing (Cognitive Styles Analysis measure) and spatial ability (Shapes Analysis Test), all subjects were asked to perform two set tasks. The first task involved subjects answering a set of short-answer questions using the medium assigned to their experimental group. The answer, when found in the Book or Hypertext required little further cognitive processing and so was thought to be a good indication of



each medium's ability to support efficient information retrieval. The second task comprised four short-essay questions based around a single fictitious scenario. Subjects were required to find information from diverse parts of the text, evaluate its relevance to the question and to synthesise an answer in their own words. The results of these two tasks are fully reported in Chapter 7, but in general it was surprising to find two things: 1) subjects in Task 1 assigned to the Hypertext group performed significantly worse than their Book counterparts, and 2) it appears from the results of statistical analysis that prior computing experience might be related in part to the performance of the Hypertext subjects on Task 1.

In comparison to certain individual differences, such as spatial ability, experience and knowledge of a specific computer system are relatively easy to change. Simple training, documentation or practice time will suffice. To evaluate the importance of this easily modifiable individual difference, a second set of experiments were initiated specifically designed to investigate the link between computer familiarity and task performance when using hypertext. Chapter 8 reports the findings of this second experiment and relates this to the first experiment and to similar studies reported in the literature.

The thesis concludes by summarising the main contributions made by the research and suggests avenues for further work. Two primary areas for further work are discussed: further investigations concerning the influence of individual differences, and secondly a call for research into Virtual Learning Environments including topics such as: longitudinal studies, learning life cycle support (Mayes & Fowler, 1999), 'HyperCurricula', adaptive hypermedia and socio-cultural research. Chapter 9 concludes by a speculative look at the possible future of hypertext. This last section acts as a longer-term frame of reference within which to place the recommendations for further research.

## 2. Higher education – changing times

“Many believe that we are going through a period of change in our civilization as momentous as that which occurred in earlier times such as the Renaissance or the Industrial Revolution – except that while these earlier transformations took centuries to occur, the transformation characterizing our times will occur in a decade or less!”

*Duderstadt (1997, p. 79)*

Duderstadt (1997) recommends that consideration must be paid to the changing nature of higher education. He states, “We must take great care not simply to extrapolate the past but instead to examine the full range of possibilities for the future.” (p. 79). Modern education is not simply a matter of small curricula changes to support new subject domains. Jarvis, Holford and Griffin (1998) identify thirteen important quantitative and qualitative changes occurring in education in recent times.

- childhood to adult to lifelong
- teacher-centred to student-centred
- face-to-face to distance
- education to learning
- the few to the many
- liberal to vocational
- theoretical to practical
- single discipline knowledge to multi-disciplinary knowledge to integrated knowledge
- knowledge as truth to knowledge as relative
- rote learning to reflective learning
- welfare provision (needs) to market demands (wants)
- classical curriculum to romantic curriculum to programme
- learning as a process to learning as content

Although the above ‘shifts’ as Jarvis, Holford and Griffin (1998) refer to them, apply to education in general, several of them are especially relevant to higher education. In particular, the current chapter explores in greater detail three specific changes. The first is a change in many subject matter domains towards greater complexity. Many courses taken at higher education level are multi-disciplinary (e.g. Human-Computer Interaction) or even integrated (e.g. Medicine), and as Spiro, Feltovich, Jacobson and Coulson (1991) suggest, at advanced levels become ‘ill-structured’. As will be discussed in Section 2.1, these authors argue that linear media are inadequately equipped to handle such complex subjects. A second important change, which will be covered in Section 2.2, has been the rapid expansion in the number of students entering higher education (Dearing, 1997). However, such expansions have rarely been matched by comparable expansions of services at many institutions. The work patterns of students are also changing with many, not only those engaged in distance learning, preferring to study at home using affordable personal computers (Heseltine, 1995). The third main change has been a much greater emphasis on efficiency. As will be argued in Section 2.3, educational efficiency has arisen mainly due to the large increase in student numbers (see Section 2.2) coupled with a funding cut per student of 40 per cent over the last 20 years (Dearing, 1997). To maintain standards, educationalists have been forced to either find more efficient ways of learning in terms of cost, or make existing methods more effective in terms of measurable outcomes. These three problems taken together are renewing interest in the development of new learning environments, especially those that are computer-supported.

## 2.1 The changing face of Knowledge

### *Increasing Complexity*

Throughout history, people have sought to broaden their understanding of the universe. Evidence of this can be seen in the breadth of subjects now studied. Indeed, as the pace of change accelerates many more are added. Evidence of this can be seen in the number of new mechanical and technological sciences added in the last fifty years or so. However, as domains mature, there is a tendency for the knowledge about them to become complex and ill-structured, certainly at advanced levels of education. Spiro, Feltovich, Jacobson and Coulson (1991, p. 25) define ill-structured domains as:

“An ill-structured knowledge domain is one in which the following two properties hold: (1) each case or example of knowledge application typically involves the simultaneous interactive involvement of multiple, wide-application conceptual structures (multiple schemas, perspectives, organizational principles, and so on), each of which is individually complex (i.e., the domain involves concept- and case-complexity); and (2) the pattern of conceptual incidence and interaction varies substantially across cases nominally of the same type (i.e., the domain involves across-case irregularity).”

Spiro, Feltovich, Jacobson and Coulson (1991) continue by suggesting that *all* domains which involve the application of knowledge in natural situations are substantially ill-structured. They even suggest domains such as Mathematics, which are typically well-structured can become ill-structured at more advanced levels of study. Spiro and Jehng (1990, p. 163) argue that some media are unsuitable for these complex domains:

“Linearity of media is not a problem when the subject matter being taught is well structured and fairly simple. However, as content increases in complexity and ill-structuredness, increasingly greater amounts of important information are lost with linear approaches and the unidimensionality of organization that typically accompanies them.”

To ensure these media/complexity mismatches do not occur, Jacobson and Spiro (1994) propose a theoretical framework that categorises knowledge domains by: 1) their

conceptual characteristics such as well- versus ill-structuredness and complexity, and 2) stage of learning from introductory through to advanced knowledge acquisition. They go on to suggest that simple introductory material may be acquired effectively using drill-and-practice, but advanced learning of ill-structured and complex knowledge requires alternative techniques, such as systems utilising Cognitive Flexibility Theory (CFT). Jacobson and Spiro (1995) discuss a hypertext system which utilised the principles of CFT; for example, the use of multiple knowledge representations, links from abstract concepts to specific case examples, and early introduction of domain complexity.

### ***Information Explosion***

The term 'information explosion' and 'information technology' are often used together. However, large explosions in the quantity of information are not solely a unique occurrence of the IT age. Robertson (1998) argues that there have been four main information explosions triggered by key inventions. Using these four quantitative changes in the amount of information available Robertson lists estimated quantities available to five different civilisations:

- **Level 0 – Pre-Language:  $10^7$  bits**

Robertson uses the crude example that the epic poem Iliad used to be memorised by various individuals. The poem contained about 5 million bits so Robertson posits that the amount of information available to an individual is likely to be within one or two orders of magnitude of 5 million bits.

- **Level 1 – Language:  $10^9$  bits**

Individuals living in a linguistic society will have access to their own memorised information and that of the other people in the village or clan (50 to 1,000 people). However, notwithstanding a large amount of commonality in the information held, such as hunting or cooking, Robertson still asserts that the information available will be one or two orders of magnitude above a Level 0 civilisation.

- **Level 2 – Writing:  $10^{11}$  bits**

Using the *Iliad* again for estimation purposes together with records indicating that the great library at Alexandria contained 532,800 scrolls, Robertson posits that the total quantity of information available in the library could have been about 100 billion bits ( $10^{11}$  bits).

- **Level 3 – Printing:  $10^{17}$  bits**

Using an almanac figure showing that 10,000 new book titles were published in the US during 1950, Robertson estimates that, including other information sources such as newspapers, periodicals and advertisements, the amount of information available to a Level 3 civilisation is about a million times greater than that available to a Level 2 civilisation.

- **Level 4 – Computers:  $10^{25}$  (?) bits**

The use of computers dramatically increases individuals' ability to process information. Robertson in 1998 writes that the amount of data generated from high-energy accelerator experiments can equal the content of the library of Alexandria in approximately five minutes. Even this figure has been eclipsed by several orders of magnitude by the year 2000. Modern accelerator experiments can output terabytes of data per second. Although it can be argued that the discussion has switched from *information* to *data*, the amount of information accessible is still unprecedented. For example, search engines on the Internet are able to index billions of words across tens of millions of web pages.

The precise figures are unimportant. What is important are the relative increases in the amount of information available to these types of civilisation and what effect it had on them. Limited information constrains the ability of a civilisation to perform certain tasks. For example, Robertson (1998) provides a convincing argument that democracies are difficult to support without printing technology.

“Assume that we have a voting population of about 100 million, that two candidates are running for office, and that each has a 1,000-word (at 25 bits per word) statement of his or her views on critical issues. Further assume that each

copy of the candidate's statement can be shared among ten voters. Simple arithmetic shows that more than  $10^{11}$  bits are required for just two candidates in a single election (not even considering the indirect information requirements). This is roughly the size of the entire library of Alexandria, which represented centuries of accumulated information."

(Robertson, 1998, p. 26)

The current importance of information to our Level 4 civilisation can be seen by analysing figures showing that over half of the gross national product of the US comes from the transfer of information and half of the workforce is engaged in the field of information (Moore, 1995). Moore lists some impressive statistics, such as the amount of new information produced in the last 30 years is greater than that produced in the previous 5,000 years, the amount of information will soon double every four years, and that about 1,000 books are published internationally every day. However, this information explosion brings with it an information retrieval problem. Of course not all these new volumes will advance knowledge but this is of little consolation to readers wishing to find specific pieces of information. Bush (1945) was one of the early visionary people to foresee this growing problem:

"The summation of human experience is being expanded at a prodigious rate, and the means we use for threading through the consequent maze to the momentarily important items are almost the same as in the days of square-rigged ships. We are being buried in our own product.... Many of them [thoughts] become lost; many others are repeated over and over and over."

(Bush, 1945, p. 102)

Thirty years later, although our resources and methods for threading through this maze are more sophisticated, for example, by use of computer-based bibliographic indexes and full-text search engines, there are still worrying economic problems. For example, Moore (1995) reports that although the amount of printed knowledge doubles every eight years, the number of books in large libraries doubles only every fourteen years. Thus, either whole fields of knowledge will be missing, unlikely in an academic library that has to support many faculties, or the coverage of any one field will diminish as a percentage of the total published. In addition to the problem of libraries holding a

reduced proportion of the information published, Taylor-Roe (1994, p. 40) highlights a growing physical storage problem:

“There is also too much to store, and we are compelled to seek ever more imaginative ways of cramming our expanding stock into finite spaces, together with ever more devious ways of disposing of older material without our academics noticing.”

Furthermore, it is not just a quantitative change in the amount of knowledge published, there are three additional problems affecting information dissemination, 1) an increase in the rate of information change, 2) spiralling costs for many publications, both books and journals, and 3) problems of accessibility. These are discussed briefly below.

### **1. Rate of information change**

It is important to differentiate between two qualitatively different types of information change, grossly defined here as depth and breadth. Within many domains, information is being created/updated within ever decreasing life-cycles. This year (2001), in computing, bookstore shelves are dedicated to Office 2000, next year the majority of these titles will be replaced with Office XP. Other domains, such as the medical sciences, genetic engineering and nano-technology, are changing at a similar breath-taking pace. However, in addition to this there is a change in the breadth of information being produced. For example, in only the last fifty years a number of completely new domains have emerged, most notably these include space flight, computing and genetic engineering. Not only are new domains born, but also others emerge from older fields to become complex fields in their own right. For example, artificial intelligence is a distinct area that has a significant independence from the parent disciplines of cognitive science and computing.

Practical evidence supporting the problems associated with these rapid information changes can be seen in some of the ‘tricks’ publishers are playing. For example in the field of computing, *The Non-designers guide to web design* which was available at the end of 1997 had a publication date of 1998, and Microsoft’s Windows 98 guide is based on a beta release (which will probably differ from the release



product). In a field which changes significantly every year, a publisher who can 'bend' a publication date by six months stands to gain by making the publications appear more up-to-date than they really are. Although book publishers are employing these tricks to try and hide the problems, Denning and Rous (1995) acknowledge the fact that authors of journal papers are becoming increasingly dissatisfied with publishing delays. Denning and Rous state that the review-revise phase of writing a paper can take 6-18 months and then another 12-18 months to actually be published. Readers are also dissatisfied when they know the results being read are 1-3 years old.

## **2. Costs**

The second major problem, cost, has direct relevance to education through its effect on library acquisition policies. As Mosher (1995, p. 40) notes, "while the volume of new publications increases exponentially... and the cost of those materials increases geometrically, the financial resources available for libraries to acquire them increases only arithmetically." To quantify the figures involved, Patel (1998) presents figures showing that between 1986 and 1997 the cost of serials in the U.S. rose by 169% while in the U.K. during the same time period the increase was 308%. Confirming Mosher's (1995) statement, statistics available from the Association of Research Libraries (ARL) shows that libraries are waging a battle they cannot win. For example, although the unit cost of U.S. serials increased by 175% between 1986 and 1998, the amount spent on serials acquisition increased only 152% during the same period (Association of Research Libraries, 1999). The effect of this was that the number of serials purchased actually decreased by 7%. Monographs show a similar pattern: between 1986 and 1998 they increased by 66% while spending increased by only 33% resulting in 25% fewer monographs purchased (Association of Research Libraries, 1999). If such rates of price increase remain unchecked they will eventually undermine the ability of libraries to maintain their current levels of service. Indeed, many libraries have dropped several serial subscriptions and are searching for other less widely read titles to remove. Worryingly, such practices are beginning to affect the integrity of these library archives (Denning & Rous, 1995). Also, because many titles may not be available

locally, libraries are increasing their inter-library loans. Between 1986 and 1998 the number of inter-library loans made by ARL Libraries increased by 151% (Association of Research Libraries, 1999). In 1993 the inter-library loan costs represented nearly 11% of the total amount spent on acquisitions by ARL libraries (Mosher, 1995). While many of the electronic pricing structures that will be available in the future are not yet in place<sup>1</sup>, there are already indications that electronic media can reduce costs significantly. For example, currently the complete Oxford English Dictionary (2nd ed.) costs £1,650 in book format, but just £293.75 on CD-ROM. Although the pricing of the Oxford English Dictionary is somewhat unique, there are signs that electronic storage costs are falling dramatically. For example, Bill Cody of IBM is quoted in *Personal Computer World* (2000) magazine as stating the following figures:

Year	Worldwide electronic storage requirements	Cost per Mb
1995	81,000 terabytes	21.0p
1999	800,000 terabytes	3.0p
2001	6,000,000 terabytes	0.4p

When the cost of electronic storage reaches the estimated 0.4p per megabyte in 2001<sup>2</sup>, Cody argues that digital storage can compete economically with paper and film.

## 2.2 Student Changes

### 3. Accessibility

The accessibility of information is rarely mentioned in the literature, but is a growing problem. Many books and journals are simply not available to readers. For example, once a book goes out of print, it can no longer be obtained via bookshops. The alternative is to try to secure a second-hand copy or find a copy in a library.

<sup>1</sup> Odlyzko (1997) presents an informative breakdown of current costs for both print and electronic journals.

<sup>2</sup> A recent advertisement in the June 2001 edition of PCW magazine confirms that this estimate is indeed accurate, with the price per megabyte for some hard disk drives as low as 0.35p.

Although the UK copyright libraries store all books published in Britain, the location of these libraries can be hundreds of miles away from much of the population. The copyright libraries do not lend books (apart from the British Library through inter-library loan) so they must be consulted within the library reading room. The photocopying of more than 10 per cent of a book is illegal, even for out of print books, so this does not represent a solution. Even when a library does have a copy of a book, only one reader at a time can consult it. Changing social mobility and study practices make it more common for distance learners and attending full-time students to spend increasingly large amounts of time studying at home. For these students, who spend some time at home working and some at the parent institution, accessing books can be problematic. For example, whereas a *single* book is relatively lightweight and portable, few people take *all* their books between home and university every day. Utilising digital representation, information could be transported easily in ‘pocket libraries’ based on CD/DVD-ROM, or even selected publications or chapters transmitted over wide-area computer networks when and where needed. In addition, with appropriate server technology it is possible for a large number of users to access the same information as if there were multiple copies. With this type of technology, libraries would no longer face the dilemma of ‘how many copies of a course textbook to buy’, as *every* student on the course could access it.

## 2.2 Student Changes

One of the most frequently cited recent changes in higher education is the rapid expansion of student numbers. Statistical information presented by Matheson and Pullinger (1999) show that the total number of students in higher education<sup>3</sup> between 1970/71 and 1996/97 tripled. This expansion looks set to continue, in the short-term, with the Committee of Vice-Chancellors and Principals (CVCP) advocating increases from 31 per cent participation in higher education to 40 per cent by 2001 (Heseltine,

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<sup>3</sup> Includes part-time, full-time and both under- and post-graduate UK students.

1995). What is not known currently is how the introduction of course fees during the 1998/99 academic year will affect future higher education participation. The short-term trend, as Table 2.1 shows, appears to be a slow down in the expansion of student numbers.

Academic Year	Total number of HE students	Increase from previous year
1999/00	1,918,970	1.5%
1998/99	1,890,775	2.6%
1997/98	1,842,332	2.5%
1996/97	1,797,081	4.5%
1995/96	1,720,094	

**Table 2.1** UK higher education student participation statistics 1995/96 – 1999/00. Data obtained from the Higher Education Statistics Agency (<http://www.hesa.ac.uk>).

In addition to the changes already outlined by Jarvis, Holford and Griffin (1998) at the beginning of this chapter, Heseltine too posits that the issue is not just a change in student numbers, but how this will transform the ‘very nature’ of higher education. He cites the following changes:

- For the first time there are more students over the age of twenty-one than below;
- Increasing part-time student numbers;
- Learning is coming to be regarded as a lifelong activity, not something sandwiched between childhood and work;
- The range of qualifications offered is being expanded;
- Students are becoming increasingly free to move between institutions and gain credit for qualifications from multiple sources;
- Distance learning is growing in importance as universities form partnerships with business, secondary and further education institutions.

In addition to the age changes and study habits (i.e. increase in part-time learning) that Heseltine (1995) mentions, there are a number of other changes including:

- **Higher Female Participation**

The number of females studying in higher education has increased from half that of males studying in 1970/71 (416,000 males and 205,00 females) to slightly greater number than males in 1996/97 (912,000 males and 980,000 females) (Matheson & Pullinger, 1999). Such significant changes in the number of females studying in higher education raises important questions concerning gender equality within academic institutions. Do current pedagogic practices unfairly advantage or disadvantage one particular gender and can females choose to study fields of interest to them?

- **Decreasing Income**

Stevenson (1995, p. 12) states, “students’ own book buying and general purchasing power have declined significantly.” So, in addition to radical institutional changes resulting from new student populations and the economics of this new situation, the students themselves are changing. Undoubtedly many students have been affected by the declining value (in real terms) of higher education grants. Between 1980/81 and 1990/91 the value of grants for students studying in England, Wales and Northern Ireland declined by an eighth in real terms (Matheson & Pullinger, 1999). Although students can now apply for an additional loan which must be repaid, the introduction of £1,000 course tuition fees in 1998/99 will place additional financial pressures on many individuals.

- **Changing Requirements**

Collis (1998) argues that changing student demographics and career mobility will make ‘lifelong learning’ not only desirable but essential. He continues by suggesting that students will require educational programmes and experiences tailored to their own situations, rather than adapting to the traditional full-time, campus-based, course oriented approach currently popular.

## 2.3 Efficiency Drive

Over the past 20 years, public funding for higher education in the United Kingdom has increased in real terms by 45 per cent, but expressed as a percentage of gross domestic product it remains unchanged (Dearing, 1997). Moreover, given the large increase in student numbers over the same period, this represents a cut in the unit funding per student of 40 per cent. The Dearing Report states that present public spending plans assume a reduction in expenditure, in real terms, of 6.5 per cent per student over the two years from 1998-99 to 1999-2000. Thorpe (1995) commenting on the situation writes:

“There is general acceptance that the circumstances for teaching in HE have changed radically and permanently, but there is no consensus around what and how to change processes of teaching and learning. However, the application of new technologies to teaching is held out as the main hope, with various approaches to the implementation of open learning already underway.”

*(Thorpe, 1995, p. 22)*

A review of educational research suggests that there are three main ways to increase efficiency:

### 1. Reduce library expenditure

As stated above, the cost of publications is rising geometrically but the resources available to purchase them is increasing only arithmetically (Mosher, 1995). With increasing raw material costs (i.e. paper) and transportation costs, it seems likely that this situation will present the largest problem for education. Already, certain academic libraries are redirecting their emphasis from *holdings* to information *access* (Stevenson, 1995).

### 2. Use computer-based learning environments

While economic efficiency is acknowledged by many to be important, the ‘Holy Grail’ of educational research has always been the development of more effective teaching/learning methods (Clark, 1994). Constructivistic learning environments, Microworlds and Intelligent-Tutoring Systems are all being investigated as

alternatives to traditional paper/lecture-based techniques. The relationship between media and theories of learning will be explored in greater detail in the next section (Section 2.4).

### **3. Increase Student Numbers**

A third possibility, without reducing the cost of media or improving its effectiveness, is to increase the size of the student population that uses the material. Thorpe (1995), referring to a report by the Scottish Universities Committee of Principals, states that it advocated the establishment of a ‘Teaching and Learning Board’ which would organise the production of shareable learning resources. Exploratory schemes such as the MANCHI project have demonstrated that it is indeed feasible to develop shareable resources by utilising networking technology. “In a very real sense, higher education is evolving from a loosely federated system of colleges and universities serving traditional students from local communities into a rapidly expanding knowledge industry.” (Duderstadt, 1997, p. 81). Duderstadt continues by warning that many within academia will be alarmed at this view of post-secondary education – a highly competitive, increasingly deregulated, global marketplace, ‘industry’ – but it is nevertheless an important perspective which requires a new paradigm for education.

The rhetoric employed by Duderstadt (1997) is radical, referring to knowledge industries, new paradigms and mass-markets. However, such language does signal the dawning of a new educational age. It is clear that future technological educational systems will need to be compatible with the new pedagogy of the 21st century. Mere extrapolation of past trends is no longer an option. The requirements which future educational systems will need to meet can be found by analysis of Duderstadt’s (1997, p. 89) conclusion:

“But perhaps even an enterprise dominated by asynchronous learning – anytime, anyplace, for anyone – may be only a transitional stage to a more radical future for higher education. Perhaps a more appropriate future for higher education – indeed, all of education – is that of a ubiquitous, pervasive learning environment – everytime, everyplace, for everybody. Indeed, in a world driven by an ever-

expanding knowledge base, continuous learning like continuous improvement has become a necessity of life."

## 2.4 Changing Theories of Learning

In addition to changes in the amount of information available and the characteristics and needs of students, learning theories too have changed over the decades. Each theory influences the educational approaches adopted including the design of educational media. It is therefore necessary to review the main theories of learning before discussing media in more detail in Chapter 4. Cooper (1993) suggests that there have been three major theories: behaviourism, cognitivism and constructivism.

- **Behaviourism**

Behaviourism can be traced back to a seminal paper in 1913 by John B. Watson entitled "Psychology as the Behaviourist Views It." Watson, taking a keen interest in the work of Pavlov, suggested that an individual's behavioural response to a given stimulus could be predicted accurately simply by observation (Kellogg, 1995). Cognitive aspects of learning are ignored, instead the mind is treated as a black-box with stimulus inputs and behavioural outputs. As Jarvis, Holford and Griffin (1998) highlight, many schools and universities use behavioural outcomes as a way of describing aspects of learning which may be measured. Statements such as "At the end of the lesson, students will be able to..." are classic forms of behavioural outcomes. Early drill-and-practice software applications influenced by the theory broke learning down into a sequential series of small steps each covering a piece of the subject domain or a particular skill (Pachler, 1999). Students are free to repeat any part of the material as many times as necessary and can proceed at their own pace. However, as both Pachler (1999) and Jarvis, Holford and Griffin (1998) warn, the theory can promote a 'passive' approach to concept acquisition whereby students seek only 'right' answers without questioning the underlying reasons. Also, the theory tends to support convergent outcomes based around the behaviour the teachers or lecturers expect. This may be useful in some subject domains, such as



undergraduate medicine, but may be unsuitable for others like computer programming.

- **Cognitivism**

One of the limitations of behaviourism is that it ignored the capabilities of the mind in learning situations. One of the first researchers to explore cognitivism was Jean Piaget in the 1930s. Conducting studies with his own children Piaget posited that individuals up to the age of 15 goes through a number of distinct cognitive developmental stages. Importantly, Piaget concluded that the closer the educational instruction matched the learner's stage of cognitive development the better (Kellogg, 1995). Spurred on by practical needs during the Second World War, cognitivism became popular in the 1950s. Instead of simply viewing the learner as a passive recipient, as did the behaviourists, this new theory concentrated on the information processing capabilities and characteristics of learners (Pachler, 1999). Cognitive aspects such as mental abilities, memory, cognitive styles and strategies were of interest as ways of explaining a learners response to given instruction or educational tasks. These cognitive aspects will be discussed in further detail in the next chapter. Also, the theory accepted the idea that knowledge was represented in a dynamic mental structure called a schema. The effect of cognitivism on computer-based instruction was a move from the behavioural programmed instruction base to more elaborate intelligent tutoring systems that could take account of learners' preferred styles of instruction and current knowledge.

- **Constructivism**

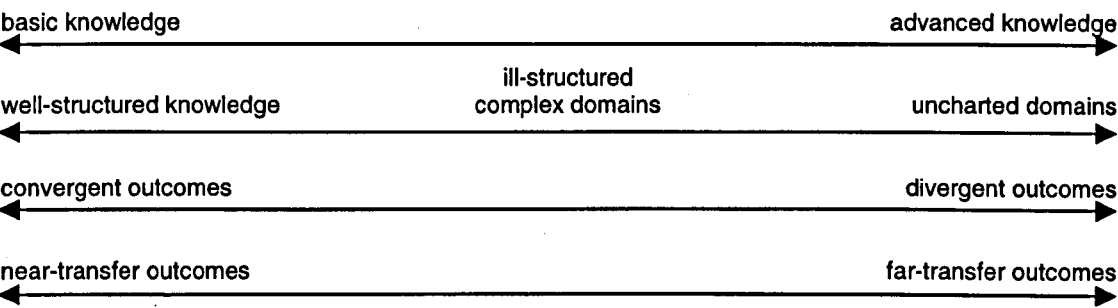
Much research into the cognitive processes of individuals is still undertaken by psychologists. What constructivism represents is an additional perspective on the learning process. Behaviourism and cognitivism are both classed as objectivistic, arguing that the human mind acts as a processor for the acquisition of *external* reality. Constructivism, however, asserts that reality is *internally* constructed by the learner, based on experience. However, Cunningham, Duffy and Knuth (1993) warn that the textbooks, which are in widespread use throughout education, are inconsistent with constructivist principles. For example, the authoritative tone and

limited perspectives presented allow the learner to be a passive recipient of information, not an active constructor of knowledge. They also argue that because books are physically complete documents they are hard to rearrange, combine or add to by students.

Cunningham, Duffy and Knuth (1993) argue that future textbooks could be based on hypertext technology to provide a medium encouraging learners to actively navigate and question a text from multiple perspectives and purposes. Although reading paper-based books is not limited to a single document, hypertext literature could make inter-document references as easy to follow as intra-document references. In such circumstances, Burbules and Callister (1996) question what constitutes the 'primary' text. They ask whether a reader who is studying Simone de Beauvoir's *The Second Sex*, and referring at various point to the original French *Le Deuxième Sexe*, is reading de Beauvoir, Friedan, or in fact something new? But hypertext not only supports personal construction of knowledge from multiple texts, but importantly it also changes the roles of both author and reader. There is a devolution of power to readers, empowering them to decide suitable reading orders, permit annotations, extensions to the document contents and even possible restructuring.

It would appear from Cooper's (1993) discussion that education has moved completely away from behaviourism to constructivism. However, what these three theories have created is a richer educational diversity. As can be seen in Figure 2.1, there are a number of knowledge and learning outcome spectrums that can be conceptualised (Cole, 1992). On the left side of the figure, there is basic knowledge that is well-structured. Solutions are often convergent and the application of such knowledge is not substantially different from that originally learnt (near-transfer outcomes). However, on the opposite side of the figure, knowledge is advanced, ill-structured or uncharted, and the outcomes are divergent and substantially different from those originally learnt. Both Cole (1992) and Jacobson and Spiro (1994) argue that different methods and theories are suitable for different parts of the spectrum. Basic well-structured knowledge, for example multiplication tables, may still be most effectively acquired using behaviouristic principles (rote learning). However, at the opposite end of the spectrum,

where ill-structured and advanced knowledge is being explored, constructivistic principles may be more appropriate. The crux of the matter, as Cole observes, is which techniques are appropriate in what circumstances.



**Figure 2.1** Knowledge and outcome continuums (from Cole, 1992, p. 28).

## 2.5 Summary

This chapter has reviewed some of the extraordinary changes that are sweeping higher education. Robertson (1998) argues that in a civilisation that invented the aeroplane, the electric light, the microchip and developed democracy on a continental scale, education is perhaps one of its greatest triumphs. However, this success is now being threatened by several pressures: changing complexity, amount and cost of information, increasing higher education student populations, and the growing emphasis on more efficient forms of teaching and learning to cope with inadequate budgets. What is becoming increasingly clear is that simple extrapolation of past educational policies will not suffice. The building of larger academic libraries that adequately met the needs of Level 1, 2 and 3 type civilisations will no longer cope with the change in the order of magnitude of information required by the current IT-based Level 4 civilisation.

The changing social circumstances of students is also driving the need for more flexible forms of education, such as open and distance learning, that do not necessarily correspond with traditional lecturing modes. At the same time as these monumental changes in information and changes in student demographics have been taking place, so too have theories of learning evolved. Starting from a behavioural perspective, the early theories treated the learner in a passive way responding in predictable ways to given stimuli. In recent decades this theory has given way to cognitivism which analyses cognitive functioning and argues for the existence of dynamic schema, and more recently constructivism which posits that reality is internally constructed by the individual. Many educators are turning to computer-based learning environments to solve the issues raised in this chapter, but more research into these alternative systems is urgently needed. One only has to look at the number of educational web sites that are appearing to see that practice is running far ahead of educational research and theory.

As Robertson (1998) posits, information is a vital pre-requisite for many of the key activities of society, but most of the statistics quoted in this chapter concern external forms of information cost and storage. For learning to occur the information must be available at the right time, place and cost for the learner, but then importantly, from a

cognitive perspective, it must be in a suitable format to be internalised into the individual's existing knowledge schema. This format will depend on various characteristics of the individual processing the information such as mental abilities, cognitive style, personality and prior knowledge and experience. The next chapter will review these individual differences constructs in more detail and review the results of research manipulating the format of these external information sources for greater educational effect.

## 3. The importance and implications of individual differences

### 3.1 Introduction

Duderstadt (1997) posits that knowledge has become the key to an individual's standard of living and quality of life in his vision of the future. As the quote at the end of Section 2.3 shows, Duderstadt imagines a possible pervasive learning environment in which *everyone* is learning. Indeed, developed countries already have school-based education for all. However, as Riding and Sadler-Smith (1992) suggest, there is a striking range of individual differences in learning performance which can be observed. They warn that the processes underlying these differences, and their effect on performance, have received relatively little attention. In a review of prior research, Bohan, Marshall and Boehm-Davis (1995) report that individual differences can account for more variation in performance than system design. They cite a text editing study which reported a performance difference as wide as 7:1, and another study, analysing programming, which found even bigger differences. In a hypermedia investigation, Dählback, Höök and Sjölander (1996) report that differences in performance as large as 19:1 were found in some spatial activities. Obviously such large differences, especially in an educational setting, pose significant problems.

Before attempting any instructional redesign, it is necessary to understand more precisely how individuals differ (along which dimensions), and more importantly which of these differences are relevant and have most effect on performance. While there is considerable variation in physical differences, the discussion here will be mainly limited to psychological differences. Operating computer software and the processes of learning are mainly cognitive activities so it is reasonable to suppose that it will be the psychological makeup of an individual which influences these activities most.

## 3.2 Mental Abilities (Intelligence)

It may appear somewhat strange to entitle this particular section 'mental abilities' instead of 'intelligence' which is included in parentheses. However, 'intelligence' is a value laden-term both in psychology and everyday usage. As a result, the term 'mental abilities' adopted by Cooper (1999) is employed in the current discussion.

Although it is not the aim of this section to elaborate in great detail about what mental abilities are, a brief overview is necessary. In general there appears to be acceptance that mental abilities refer to *what* information is being processed – what kind of information is being processed by what operation and in what form (Messick, 1976). This should be contrasted with cognitive styles which represent *how* information is processed – the manner in which behaviour occurs (see Section 3.4). However, beyond this agreement concerning what information is processed, experts in the field are at odds regarding the best method of measuring and describing this ability(s). For example, early researchers (e.g. Spearman (1904)) argued in favour of 'general-intelligence' or 'g-factor'. Spearman (1904) arrived at this conclusion by comparing individuals' performance on a number of different measures using statistical factor analysis. In general it was found that if an individual performed above average on one test then they were likely to perform above average on the other tests. Over thirty years later Thurstone (1938) used factor analysis again but found no significant correlations between the various tests. This led Thurstone (1938) and more recently Gardner (1983) to argue in favour of a multiple frames approach to mental abilities. Instead of employing a single g-factor, an individual's mental abilities are described using a number of different measures: verbal relations, perceptual speed, numerical facility, word fluency, memory, induction, restriction, deduction and spatial ability. Some contemporary researchers are now pursuing a hierarchical model of mental abilities (e.g. Cooley & Lohnes, 1976; Carrol, 1993). This method of decomposing mental abilities is a compromise between the two extremes arguing on the one hand for a single g-factor and on the other for the existence of multiple abilities. At the top of the hierarchy, or root, there is the acknowledgement of general intelligence, while at successive levels this general ability is broken down

into more specific abilities similar to the multi-ability models favoured by Thurstone (1938) and Gardner (1983).

One ability common to most of the multiple component models of mental ability is the notion of 'spatial ability'. "Central to spatial intelligence are the capacities to perceive the visual world accurately, to perform transformations and modifications upon one's initial perceptions, and to be able to re-create aspects of one's visual experience, even in the absence of relevant physical stimuli." (Gardner, 1983, p. 173). Although most tests used to assess spatial ability are visual, some can be expressed textually. As Gardner (1983) highlights, there is some debate within the field as to whether such transformations truly rely upon a visual ability or in fact use mathematical ability. For example, some questions such as "how many squares exist after a square of paper is folded in half and then fold in half twice more?", could be solved by multiplying  $2 \times 2 \times 2$ . Others, for example Höök, Sjölander and Dahlbäck (1996), argue for the existence of two distinct forms of spatial ability. One that is a grounded real-world ability whereby the individual receives feedback from the environment such as a map reading, and a second that is a purely cognitive in nature such as the mental rotation of geometric shapes.

What is particularly interesting about spatial ability is its influence in a multitude of tasks. Whereas mathematical and linguistic ability undoubtedly relate strongly with specific taught subjects, spatial ability appears to interact not with the subject matter content but with the user interface aspects of the media itself. For example, Vicente, Hayes and Williges (1987), found a significant relationship between spatial ability and navigational efficiency within a simple 15 file, 3 level hierarchy computer system. Low spatial ability subjects took twice as long as high spatial ability subjects to search for two sets of 12 targets. In a separate study, Benyon (1993) evaluated the importance of spatial ability and user interfaces to databases. Low ability subjects took 35% longer than high ability subjects when interacting with a command interface. However, the difference between these two groups narrowed to just 1% when a menu type user interface was tested. It should be noted that both interfaces employed exactly the same database. Results from both the Vicente, Hayes and Williges (1987) study and Benyon's



(1993) work suggest the possibility of redesigning interfaces to accommodate disadvantaged individuals.

Research has also been conducted using hypertext systems. McGrath (1992) investigated four different media: hypertext, paper, menu-driven computer-aided instruction (CAI) and NoMenu (basic page turner). Results from a number of mathematical tasks revealed that subjects with higher spatial ability spent more time completing the task, scored higher marks, viewed less screens out of sequence, and viewed fewer screens than low spatial subjects did. McGrath concluded that low spatial subjects become confused when using hypertext and tend to view a lot of different screens in a short period of time. Höök, Sjölander and Dahlbäck (1996) discuss another hypertext study in which subjects were required to locate six pieces of information using an online manual. High spatial ability subjects spent on average 17 minutes completing the task, whereas low ability subjects spent 25 minutes. Given that the number of clicks made by each group was statistically similar, the researchers conclude that low ability subjects spent more time studying each page. Chen and Rada (1996) present a meta-analysis of hypertext research literature. They report that three studies investigated spatial ability and found a positive relationship between ability and efficiency of interacting with hypertext. They also report that the inclusion of graphical maps within the hypertext had the effect of narrowing the differences in performance caused by spatial ability.

Two important points emerge from this literature. Firstly that spatial ability is an important factor influencing performance on a range of computer-based tasks, including navigating hypertext. Secondly, performance variance can often be reduced by careful redesign of the user interface.

### 3.3 Personality

The precise meaning of the term 'personality' is open to some debate. Some psychologists use the term to refer to all the ways in which individuals can differ from one another including social, behavioural, emotional and intellectual functioning, while others include only the social and emotional aspects of behaviour (Birch & Hayward, 1994). Even taking the social and emotional aspects of behaviour that are common in both definitions of personality, there is still scope for controversy. Some experts, for example, defend an *idiographic* approach which seeks to investigate how an individual differs, whereas others favour a *nomothetic* stance which emphasises similarities between individuals. The methods used to categorise personality also differ. Some experts, such as the early Greek psychologist Hippocrates categorised individuals into four personality *types*, whereas most contemporary researchers use a multiple *trait* based approach which uses a number of categories to describe each individual. Stability of personality is another aspect of personality which Birch and Hayward (1994) suggest is open to debate. Those researchers adopting the trait approach to personality description argue that each trait is stable and that individuals will behave in consistent ways across situations. However, Mischel (1968) argues instead that it is the current situation in which an individual finds themselves which influences behaviour most.

Leaving aside the minefield of personality definitions it is interesting to see if there is any evidence to suggest that personality is important in learning situations. The Myers-Biggs Type Indicator (MBTI) is one of the more popular methods of assessing personality. This is a multi-trait method which categorises individuals on four bipolar dimensions:

- Extroversion vs Introversion
- Sensing vs Intuition
- Thinking vs Feeling
- Judging vs Perceiving

The MBTI is administered by way of a self-reporting questionnaire which takes about 20 minutes to complete. Results can either be used to classify individuals in discrete mode (e.g. Extrovert or Introvert), or in continuous mode by assigning a numeric value from 0 to 200 on each of the four dimensions to indicate strength (100 equals a neutral position).

Matta and Kern (1991) utilised the MBTI as a method of explaining the performance of subjects learning in class (control group) and learning from interactive video disc. The results are quite mixed for each of the MBTI scales. Matta and Kern found that the thinking-feeling scale had no significant influence on students' performances. It was hypothesised that thinking individuals would perform better on the video disc since they are more analytical and do not rely as heavily on social interaction during learning as more feeling individuals do. On the Extroversion-Introversion scale it was found that introverts performed better than extroverts in both class and video disc groups. The most conclusive result was found on the Sensing-Intuition dimension. Sensing-type individuals performed significantly better than intuitive-type individuals when assigned to the video disc group. This result confirmed Matta and Kern's (1991) first hypothesis that sensing individuals would perform better on the video disc since they prefer more objective data collection, are more patient collecting information and focus more on details than intuitive individuals. Also, the intuitive subjects prefer further stimulus through human interaction which was reduced in the video disc group. In another study involving the Myers-Biggs Type Indicator, Kelleher and Coury (1993) found the amount of time required to learn to process various information display types differed with personality type. For example, subjects with an intuitive-feeling style were fastest responding to the polygon and digital display formats rather than the bargraph display.

One trait common to a number of different personality constructs is extroversion-introversion. Using the Eysenck Personality Inventory to measure this trait, Richter and Salvendy (1995) investigated the relationship between personality and user interface design. To test their hypotheses Richter and Salvendy developed a number of HyperCard systems with user interfaces designed specifically for introverts and for extroverts. The extrovert user interface, for example, contained more words, more

sounds and had a quicker pace of screen changes compared with the introvert user interface. Differences in pictures and level of humour included are also reported. The study found that although the fastest task completion times occurred when user interface style matched personality, the extrovert subjects did not perform significantly worse on the introverted user interface than they did on the matched interface. However, the reverse was not found to be true. Introverted subjects performed significantly poorer on the extrovert user interface than the extroverted subjects. This finding led Richter and Salvendy (1995) to recommend the development of introverted user interfaces so that task performance times could be minimised for the broadest range of users.

### **3.4 Cognitive Style**

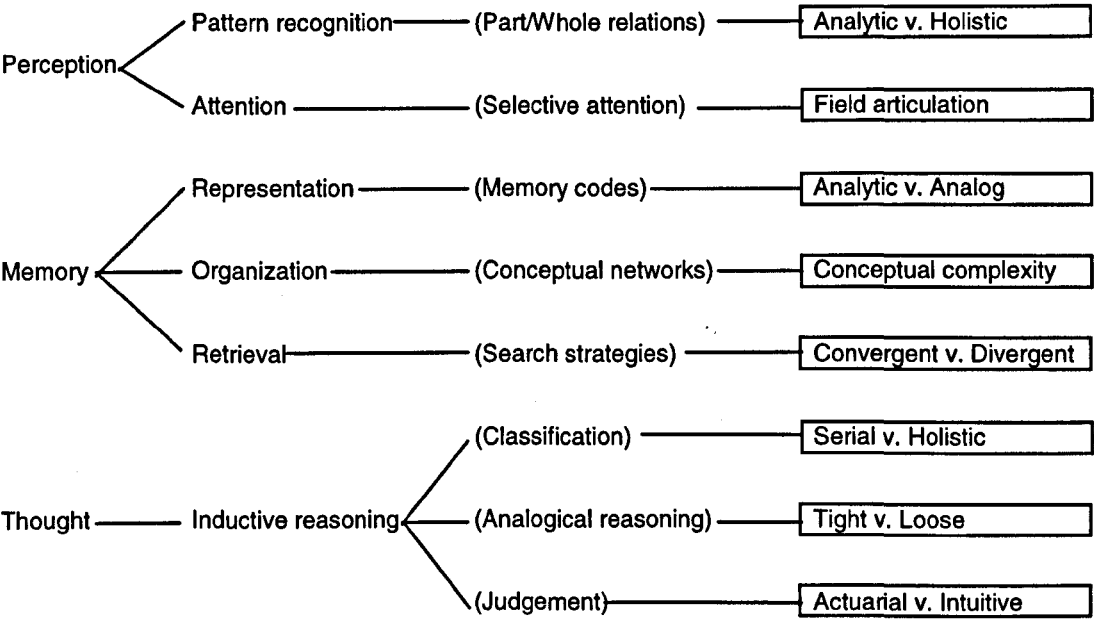
Thus far the two most popular psychological constructs, mental abilities and personality, have been briefly covered together with empirical studies highlighting their importance in computer-assisted learning. However, a third facet of individual cognitive differences lies somewhat between intelligence and personality. As this section will show, cognitive styles influence *how* information is processed and as a result exhibit behaviours normally associated with both intelligence and personality.

#### **3.4.1 Relationship with Mental Abilities**

The term 'Cognitive Style' refers to characteristic ways in which an individual processes information. The construct differs from mental abilities discussed above in Section 3.2 in two main ways. Cognitive styles are bipolar whereas mental abilities are unipolar, and cognitive styles are value neutral (Messick, 1976). For example, in the vast majority of circumstances an individual with greater mental ability will perform a task better than an individual with less ability. However, an individual with cognitive style *x* will perform some tasks better whereas individuals with cognitive style *y* will perform different tasks better and vice versa. As a concrete example, Riding and Cheema (1991) argue that mathematical, scientific or technological tasks favour

subjects with a 'convergent' style, but conversely tasks such as artistic projects favour 'divergent' styles of thinking. However, subjects with greater mathematical or linguistic ability will usually perform better than subjects with less ability regardless of task type. The precise relationship between cognitive styles and mental ability can best be illustrated by a simple analogy. Mental abilities can be thought of as a collection of specialised computer chips, for example a maths co-processor to handle mathematical tasks and a graphics chip to process spatial data. Computers with faster chips (brains with greater mental ability) can complete more complex tasks and in a shorter time than machines with older and slower chips. Continuing the computer metaphor, an analogy can be drawn between cognitive style and the function of an operating system. For example, an Intel central processing unit (CPU) could run MS Windows, Linux or Sun Solaris operating systems. The speed of the underlying hardware (CPU) will dictate the overall operational speed of the system, but it is the operating system that will affect how the hardware is managed and the data files stored and retrieved.

Just as a computer operating system has to support many different file functions, so too does the human brain, be it at a somewhat more complex level. As Figure 3.1 shows, cognitive styles influence the acquisition of new knowledge through perception, the organisation of knowledge in memory, and the practical application of knowledge in thought (Miller 1987).



**Figure 3.1** A model of cognitive styles and cognitive processes (from Miller, 1987, p. 253).

Like mental abilities and personality, although experts are in agreement on the general definition of such concepts, there is little agreement on the specific measures. Although only eight cognitive styles are listed in Figure 3.1 (see boxed items), Riding and Cheema (1991) found more than 30 different styles named in the literature. Since it is impractical to work efficiently with over 30 styles, Riding and Cheema (1991) and Miller (1991) propose a rationalisation of the various styles. They argue that many of these ‘individual’ styles may actually be measuring the same type of information processing behaviour. There is much commonality between Riding and Cheema’s (1991) ideas and Miller’s (1991). Since Riding and Cheema (1991) created a measuring instrument for their style, the current discussion will be limited to their ideas. After reading various descriptions, methods of assessment and effects, their solution was to propose two orthogonal dimensions that broadly represent many of the original ‘styles’. The first dimension, termed Wholist-Analytic, represents *process*, that is whether stimulus material is attended to as a whole or in more focused parts. The second dimension, termed Verbaliser-Imager, represents how information is *represented* internally by subjects – either visually or verbally. The individual cognitive styles associated with each dimension can be seen in Table 3.1.

Wholist-Analytic		Verbal-Imager	
Field-dependent	Field-independent	Extravert	Introvert
Holist	Serialist	Verbaliser	Visualiser
Impulsive	Reflective		
Levellers	Sharpeners		
Surface	Deep		
Divergers	Convergers		
Lumpers	Splitters		

**Table 3.1** Cognitive styles represented by the Wholist-Analytic and Verbal-Imager dimensions (from Riding, 1991).

Although cognitive styles can be assessed using introspective self-reports or tests of information processing, Riding (1991) implemented the latter method using computer software. Introspective self-reports can suffer from the following limitations: 1) the possible inability to accurately and objectively report one’s own style, 2) unwillingness to respond accurately, and 3) response bias due to social conformation pressures. An additional advantage cited by Riding and Cheema (1991) for their Cognitive Styles Analysis (CSA) software is that it measures positively both ends of each stylistic dimension (wholist-analytic and verbal-imager). Various other cognitive style tests suffer from the problem of only measuring one type of style and inferring the opposite style when performance is poor. Riding and Cheema (1991) claim that such tests are more relevant to the notion of ability than of style.

**3.4.2 Relationship with Personality**

Although there is a clear link between cognitive styles and mental abilities when individuals are engaged in cognitive tasks, there is also an interesting relationship with personality. Witkin *et al.*, (1977) found, after reviewing a number of investigations of cognitive style, that there are consistent relationships between style and educational/vocational interests. For example, individuals with a field-independent cognitive style prefer domains where their cognitive skill in analysis and restructuring will be utilised. Individuals with a more field-dependent style were found to prefer

domains involving a greater social emphasis: social worker, minister, rehabilitation officer, probation officer. In more recent studies involving the Cognitive Styles Analysis system, Riding and Rayer (1998) found a number of relationships between the two stylistic dimensions of CSA and various 'personality' dimensions. For example, they found that individuals who tended towards the very extremes of the wholist/analytic dimension were indecisive. In contrast, the intermediates (neither wholist or analytic) were found to be more decisive. Social behaviour can also be influenced by cognitive style. In an investigation of 149 undergraduate students Riding and Wright (1995) found wholist individuals tended to be more assertive, humorous and helpful, whereas the analytic individuals were more shy. Figure 3.1 also shows a link between the verbaliser-imager cognitive style and the extravert-introvert dimension of personality. As already discussed above (see Section 3.3), Richter and Salvendy (1995) found that different interface designs using varying amounts of text and graphics were related to a subjects' extravert or introvert score as measured by the Eysenck Personality Inventory test.

### **3.5 Learning Strategies**

Thus far the discussion has focused on the stable psychological constructs of mental abilities, personality and cognitive style. However, learning strategies are also important cognitive approaches to learning. They are defined by Riding and Rayner (1998) as a set of one or more procedures that an individual acquires to facilitate performance on a learning task. They go on to discuss four important stages in the development of strategic learning:

#### **1. Sensing and preferring**

When presented with a learning situation an individual will sense how appropriate it is for them. Typical dimensions on which the instruction can be assessed by the learner include mode of presentation, structuring of the task and the social context of learning.



## 2. Selecting

If presented with a choice of learning materials individuals will often select those matching their cognitive style. For example, 'imagers' will tend to select graphical instruction, whereas verbalisers will tend to select textual material. As will be reported in Section 4.5.2, empirical confirmation of selection techniques in relation to hypertext navigation was found by Leader and Klein (1996).

## 3. Extending the learning strategy

When instruction does not optimally match the individual's cognitive style, various learning strategies can be extended to make the instruction more suitable. *Translation* involves the learner converting information in one format into another more suitable format. For example, an imager might draw a diagram after reading a piece of text, to aid comprehension. *Adaption* can be employed to change the 'perspective' of the information. For example, an individual with an analytic-imager cognitive style (very focused) could use a diagram to help obtain a broad overview of the current task. A third extended learning strategy is *reduction of processing load*. In this situation an imager, for example, who finds verbal processing cognitively demanding, could opt to selectively scan the text to extract only the important sections.

## 4. Developing a repertoire of learning strategies

Over time an individual will develop a range of different successful learning strategies for use with future tasks.

Although a learner can apply an extended learning strategy to alter the form of instruction if it does not match their preferred style, this ability appears dependent to some extent on mental abilities. For example, Riding and Agrell (1997) found that the largest differences in performance occurred when the teaching material did not match the style of the learners. In this case it would seem that additional cognitive processing (intelligence) had to be diverted in order to change the information into a format that could easily be assimilated. So, continuing the computer analogy used earlier it would appear that just as only the fastest PowerMac computers can emulate IBM compatibles

through software, so too, are individuals limited in how much emulation they can perform given a set of mental abilities.

### 3.6 A holistic view of psychological differences

As seen in the previous sections, mental ability, personality, cognitive style and learning strategy are important facets of an individual’s cognitive approach to learning and problem solving. However, although these facets are clearly related, their precise interactions with regard to a learning situation have not yet been discussed. Riding and Rayner (1998) propose that an individual experiences world events through perception and working memory (see Figure 3.2). This is then ‘filtered’ initially by the cognitive control level (cognitive styles). The individual then uses past knowledge to process a response; this is influenced by personality and gender also. The cognitive control layer is then employed a second time in the problem solving process since it influences selection of learning strategy. Finally, depending upon which particular learning strategy is selected, a range of externally observable behaviours can be seen.

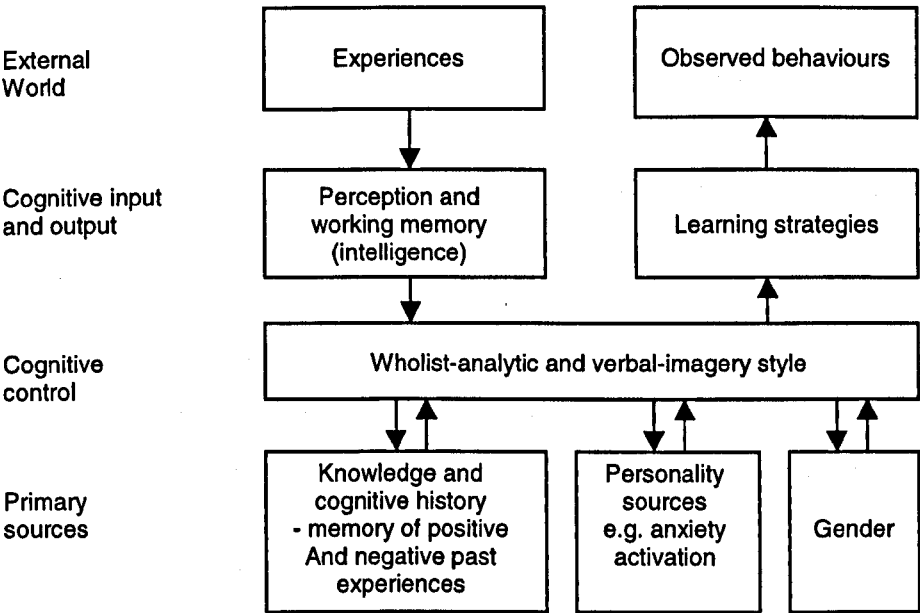


Figure 3.2 Cognitive control model (from Riding & Rayner, 1998, p. 115).

## **3.7 Accommodation: the implications of individual differences**

### **3.7.1 Practical Limitations**

Before discussing how various individual differences may be accommodated, it is important to realise the inherent limitations of individual differences research. Firstly, categorising the various differences which can be measured is contentious. Even the very scope of some of the broad constructs, such as personality, is open to debate. For example, depending upon the precise theoretical basis, some experts include social, behavioural, emotional and intellectual functioning under the term 'personality', while others would classify only the social and emotional aspects of behaviour under this term (Birch & Hayward, 1994). Secondly, from a practical perspective, there are limitations associated with developing instruction specifically designed for certain individual abilities. For example, it is common practice within the educational psychology literature to convert continuous measures on a particular cognitive spectrum and translate these into discrete labels such as low spatial ability or high spatial ability. Notwithstanding that two simplified poles may not be sufficient to cope with all the differences encountered, there is the problem that this is only one individual difference variable. If another is added, such as mathematical ability, and assuming there is no relationship between these variables, four different instructional treatments will be required: 1) low spatial, low mathematical, 2) low spatial, high mathematical, 3) high spatial, low mathematical, and 4) high spatial, high mathematical. As this simple example shows the number of different instructional treatments required increases exponentially as new individual differences are accommodated. The ultimate logical conclusion is that each individual receives a completely unique form of personalised instruction. It would appear that there are parallels with the way the clothing industry tries to accommodate various physical differences. At one end of the spectrum there are a few garments which can be mass produced very cheaply in a form of 'one size fits all' (e.g. gloves and baseball caps). In the middle of this theoretical continuum are the off the peg pre-set sizes which are a balance between perfect accommodation of the physical differences and the costs of producing the garment. Approaching the other end of the spectrum, solutions such as bespoke tailoring emerge that can create optimal

matches between clothing and physical differences but are the most expensive solution to develop. In education the two ends of the continuum are equally covered from the one size fits all lecture to the personal meeting with a tutor. What remains unknown is what are the best strategies to use when designing instruction to maximise the accommodation of individual differences, and, at the same time, minimise development time and costs.

### 3.7.2 Types of Accommodation

#### *Individual Adaptation*

Starting at the 'one size fits all' end of the spectrum, in some circumstances it might be possible for the individual to adapt to the instruction if it is not in the most suitable format. However, there is some debate regarding how easy it is for an individual to change their various styles and abilities. Some, for example physical differences, remain quite static, only changing slowly with age or possibly suddenly through injury or disease. The changeability of psychological differences is more open to debate. Witkin *et al.* (1977) argue that although cognitive styles are stable over time, this does not imply that they cannot be changed. They claim some may be altered easily just by asking an individual to think in a different way. As stated earlier, cognitive styles may be conceptualised as being bipolar. Being at one end of a style dimension can be advantageous for some tasks while for other tasks, the opposite end of the spectrum would be better. However, Pask (1976) suggests that there are *versatile* individuals who lie between his *holist* and *serialist* extremes. These versatile learners are able to switch between holist and serialist strategies to suit the characteristics of the task at hand. Although increased versatility seems a desirable goal, Miller (1991) believes that any cognitive style changes achievable would be superficial, short-term and "that wholesale attempts to encourage stylistic versatility in *all* students is not only a waste of time and resources, but also can be psychologically damaging." (p. 235). The alternative to matching individuals to educational programmes, is to alter the programmes to *match* the learners. Chen, Czerwinski and Macredie (2000) suggest there are three main ways

to achieve such a match: 1) capitalisation match, 2) challenge match and 3) compensatory match.

### ***Capitalisation Match***

The capitalisation match approach seeks to employ educational programmes that take advantage of and capitalise the strengths of the individual. Although Cronbach and Snow (1977) found few consistent results in a literature review they conducted looking at matching learning styles to instructional treatments, others around the same period did observe success. For example, Pask (1976) found that students assigned to a *matched* group were able to answer most of the questions, whereas the *unmatched* group generally scored less than half marks. More recently, Riding and Sadler-Smith (1992) found, when using three instructional treatments with their CSA measure of cognitive style, a 68 per cent difference in performance between the most appropriate match and the most inappropriate match. Ford and Chen (2001) too, mentioned again in Section 4.5.2, found significant differences with matched groups and their CSA test scores. Also, Andris (1996), using a cognitive style measuring modality preferences, found 'high auditorys' spent 50 per cent more time per node than 'low auditorys' and accessed 40 per cent fewer nodes in a hypertext system. Andris (1996) reports that the system contained much visual information and so it was likely that the high auditory subjects had difficulty assimilating the information, which resulted in the poorer performance.

### ***Challenge Match***

It is clear that several studies have had success with the *capitalisation* method of matching styles with different instructional approaches, but conversely Presland (1994) raises the interesting notion of deliberately creating more challenging learning environments by *mismatching* instruction to individuals. Becoming lost within a hyperspace is often mentioned as a problem in the literature (e.g. Nielsen, 1995), but instead of seeking ways to address this issue Mayes, Kibby and Anderson (1990b) appear to embrace it as a way of creating a challenge match. "Since the point of discovery learning is that the learner is continually engaged in a process of trying to map the information being discovered to her own developing framework of

understanding, then ‘getting lost’ may be regarded as a desirable or even necessary part of the process of understanding.” (Mayes, Kibby & Anderson, 1990b). Chinien and Boutin (1993) also argue that although matching instruction to various styles may improve short-term outcomes, there are a number of longer-term moral and ethical issues related to students only engaged in one cognitive style.

### ***Compensatory Match***

The third approach discussed by Chen, Czerwinski and Macredie (2000), aims to offset deficiencies within an individual by providing mediators, modalities or organising structures that the user cannot provide for him or herself. Stanney and Salvendy (1995) found that by using 2D visual mediators to structure information there were no significant differences between high spatial ability individuals and low spatial ability individuals.

### **3.7.3 Reflection on past practice**

Although there have been several projects illustrating significant benefits of matching instructional environments/practices to specific individual differences using the *capitalization match* method, some of this research, on reflection, appears somewhat artificial. For example, Pask (1976) matched subjects’ operation and comprehension styles with treatments designed specifically to suit these styles. While the results of this experiment do tend to support the validity of a learning style construct, it is less clear how applicable these results are to real-world learning situations where instruction/methods have not been explicitly designed around styles. In the current economic climate it is unrealistic to expect that publishers and educators will develop several different versions of every publication. What is more likely is either the intelligent adaptation of a single document (using software, see ‘Adaptive Hypermedia’ in Section 9.2.2) or the use of publications employing *compensatory match* approaches to limit performance variation resulting from stylistic differences in readers. This latter type of document could be created by using analysis of individual differences to support the redesign of material which seeks to improve the performance of weaker subjects

without adversely affecting the higher performers. Support for this proposal can be found in Riding and Sadler-Smith's (1992) data. They evaluated the performance of four groups of subjects<sup>4</sup> with three different instructional versions<sup>5</sup>. Their finding was that Analytic-Imagers showed the most difference between best match (Version 2, 83%) and worst match (Version 1, 53%). However, what is interesting is that all four groups of subjects performed within 4% of each other when assigned to Version 3. The only group disadvantaged by Version 3 was the Wholist-Verbaliser subjects (4% poorer). All three other groups performed better on Version 3 than either Version 1 or 2. Similarly, in a study of field dependence and hypertext facilities, Weller, Repman, Lan and Rooze (1995) found that although field-independent subjects performed better than field-dependent subjects, the most suitable treatment for *both* styles was the 'no structural organizer' version. Studies by Vicente, Hayes and Williges (1987) and Benyon (1993), discussed above, also point to the use of individual differences as 'tools' for the detection of style-related usability problems. Undoubtedly more research is needed in this area, but if found to be reliable, these new tools could be used to create single economic versions of instruction suitable for many different types of individual.

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<sup>4</sup> Wholist-Verbalisers, Analytic-Verbalisers, Wholist-Imagers and Analytic-Imagers.

<sup>5</sup> Version 1: large chunks of verbal information plus minimal graphics; Version 2: small chunks of verbal information with maximum graphical content; Version 3: same as version 2 but with the addition of an Organizer.

### 3.8 Summary

A wide variation in performance can often be recorded on a number of academic measures for a variety of students learning the same subject in the same mode (lecture, self-study, practical). While few doubt the importance of various cognitive differences in the way individuals approach learning situations, there is debate about how knowledge about such differences can guide practical instructional design. Two main problems dominate the field: 1) what are the best ways to categorise individual differences – and which differences are most relevant to academic performance, and 2) given a particular difference what is the best way to improve performance? Some researchers have found benefits, in terms of academic performance, when students with particular styles are allocated to ‘matching’ instructional treatments (Andris, 1996; Pask, 1976; Riding & Sadler-Smith, 1992) that capitalise on their particular style or ability. However, others argue that locking students into a single mode of thinking could be damaging in the long term (Chinien & Boutin, 1993) and in fact creating deliberate mismatches to challenge the individual can raise performance (Mayes, Kibby & Anderson, 1990b; Presland, 1994). Some empirical studies investigating matches/mismatches lend support to the idea of a single treatment which can compensate an individual where their own ability do not match the task (Benyon, 1993; Weller, Repman, Lan & Rooze, 1995). Chinien and Boutin (1993) suggest the need for a cognitive-style-focused instructional design that could attenuate what they refer to as cognitive style bias, but at the same time not force students into a single mode of cognitive functioning.

Returning to the main theme begun in Chapter 2, the limitations of books are becoming all too apparent in the rapidly changing sphere that is higher education at the beginning of the twenty first century. Proponents are suggesting that alternative media, such as hypertext, can be valuable educational tools. However, the change from traditional paper-based book to hypertext-based e-book is not necessarily simple from an educational psychology perspective. The loss of physical tactile cues afforded by a paper book and the increased navigational possibilities/cognitive load could have important implications given an individual’s spatial abilities or field-dependence style.



The next chapter will review these differences between book and hypertext in greater detail before the methodology of the current research is covered in Chapter 5.

## 4. The rise of Hypertext

### 4.1 Introduction

Chapter 2 reviewed the many pressures which are causing higher education to adapt and update practices. Part of this process of change has been a greater understanding of individual differences (discussed in Chapter 3) and an increased willingness on the part of educators to change their teaching styles to facilitate a better match with such styles and hence aim for more productive learning. Also, the extraordinary processing power of computers is being increasingly used to support various learning activities: instructional presentation, personal knowledge construction, group learning and open/distance learning. Hypertext in particular has been suggested by several experts to be a suitable educational medium (Beeman, Anderson, Bader, Larkin, McClard, McQuillan & Shields, 1987; Cunningham, Duffy & Knuth, 1993; Jacobson, & Spiro, 1995). This chapter begins in Section 4.2 by analysing the somewhat controversial statement that the medium is the message, first suggested by McLuhan (1964). A brief review establishing how various properties of media have evolved is then made and the practical consequences of such changes before concentrating more specifically on hypertext, one of the latest media forms. Section 4.3 continues by providing a more detailed review of the functionality and design of modern hypertext systems. The various applications of such functionality are reviewed in Section 4.4 including: information retrieval, writing tool, education and document management. Section 4.5 then focuses in more detail on some of the specific findings from empirical hypertext research.

## 4.2 Media

### 4.2.1 Is the Medium the Message?

“In a culture like ours, long accustomed to splitting and dividing all things as a means of control, it is sometimes a shock to be reminded that, in operational and practical fact, the medium is the message.”

(McLuhan, 1964, p. 7)

Few statements have created as much debate as the above quotation suggesting that the message, or content, can be changed and affected by the medium. Support for this assertion can be found in some of the literature investigating various forms of media. For example, Walma van der Molen and van der Voort (1998) found, in a study utilising television, transcript and two different newspaper versions, that children recalled significantly more information in the television group. Others, for example Salomon (1979), argue that it is specific media *attributes* that enable the development of unique cognitive processes and therefore differences in learning. For example, television supports ‘zooming’ into salient details and sophisticated visual effects such as ‘unwrapping’ a country from a three-dimensional representation of the world into a two-dimensional map. However, the ability of media to affect learning is called into question by Clark (1994):

“If there is no single media attribute that serves a unique cognitive effect for some learning task, then the attributes must be proxies for some other variables that are instrumental in learning gains.”

Clark (1994, p. 22)

Clark (1994) suggests that if it is accepted that media are no longer unique in the learning effects they produce, then the debate can shift from media attributes as causal in learning, to media attributes as causal in the cost-effectiveness of learning. Although Cobb (1997) asserts that Clark’s medium *uniqueness* is unassailable, since no particular medium will ever be necessary for a particular type of learning to take place, he counters by introducing the notion of *cognitive efficiency*. Cobb (1997) states that while

different media may not create different cognitive *products* (i.e. concepts, schemas, mental models), they do create different cognitive *processes*. As evidence of this, Cobb (1997) uses the example of learning bird calls. This, he suggests, could be accomplished by reading a book about the calls or listening to an audio cassette of each call. Common sense argues that the cassette is cognitively more efficient. However, there is a difference in method – the book uses definition and description whereas the cassette employs exemplification. But Cobb (1997) develops his argument by suggesting that the two methods could be aligned if the bird calls were printed in the book as sheet music. Both now use exemplification but the cassette is still cognitively more efficient. Empirical corroboration of Cobb's (1997) cognitive efficiency theory is reported by Aust, Kelley and Roby (1993). These authors evaluated the use of hyper-reference (based on hypertext) and a conventional paper dictionary. They found that subjects using the hyper-reference dictionary consulted it approximately twice as often as subjects using a conventional paper-based dictionary. Also, subjects using the hyper-reference dictionary spent nearly 20 per cent less time studying than the conventional dictionary subjects. The researchers argue that the hypertext enabled more efficient access to definitions, which resulted in increasing the subjects' appetite for elaboration. Returning to Clark's (1994) thesis, he argues for the conceptual separation of what he calls *delivery technologies* which influence cost and access to instruction, from *design technologies* that influence student achievement. "In my view, there is a long history of a basic confusion between these two technologies that strangles our study of the contributions of media." (Clark, 1994, p. 23). However, this ignores the possibility of feedback from delivery advantages affecting student achievement. In the Aust, Kelley and Roby (1993) research discussed above, comprehension was not found to be different between users of hyper-references and conventional editions of the dictionary. However, given that hyper-references subjects spent less time studying, it could be argued that over time a greater amount of learning would be possible using the hypertext system. Thus, although the difference between books and hypertext can mostly be attributed to differences in their delivery technologies, there are still important educational implications that merit further research.

An additional argument in favour of the influence of the medium is provided by Drexler (1996). Instead of viewing media as simple communication vehicles between authors and readers, Drexler discusses how the medium can affect the evolution of knowledge. For example, he states:

“Consider how the lack of modern print media would hinder the process: Imagine research and public debate in a world where all publications took ten years to appear, or had to contain at least a million words apiece. Or imagine a world that never developed the research library, the subject index, or the citation. These differences would hinder the evolution of knowledge by hindering the expression, transmission, and evaluation of new ideas.... The naïve idea that media are unimportant in evolving knowledge – that only minds matter – seems untenable.”  
(Drexler, 1996)

This view that media can facilitate or hinder the evolution of knowledge is very similar to the views expressed by Bush in 1945:

“He [mankind] has built a civilization so complex that he needs to mechanize his record more fully if he is to push his experiment to its logical conclusion and not merely become bogged down part way there by overtaxing his limited memory.”  
(Bush, 1945, p. 108)

Obviously it is not possible within the scope of a single research project to investigate the effect any medium can have on the overall evolution of knowledge as such changes can only be measured over decades. It is nevertheless possible to evaluate the potential of a particular medium to circumvent some of the limitations experienced with traditional media. If these ‘lab-trials’ are successful, then it paves the way for more extensive field testing using more diverse subject matters and user groups engaged in real-world situations.

## 4.2.2 The evolution of media properties

In addition to the influence a medium can have on the message it contains, so too does the medium affect several other important aspects:

- **Cost**

The human cost of writing has remained similar over the centuries in terms of cognitive effort and time required. However, what has fallen dramatically is the monetary cost associated with storing writing on suitable media (papyrus, paper, magnetic disk) and the cost associated with copying this information (scribe, printing press, operating system). For example, Avrin (1991) argues that printing would have been prohibitively expensive when first invented if a cheaper substitute to parchment (i.e. paper) had not been available. As already mentioned in Section 2.1, the costs of UK paper-based serials increased by 308% between 1986 and 1997. With the UK Retail Prices Index (RPI)<sup>6</sup> increasing by 60% for the same period, it seems highly unlikely that the increases in the cost of serials can be sustained for the middle to long-term based on current rates. Although there are a number of different costs associated with creating electronic media, such as hypertext or CD-ROMs – authors, programmers, graphic design artists, usability engineers – the cost of manufacture in bulk can be much cheaper than paper. Allowing twice the number of users to read the same information on a web site often costs exactly the same; only large increases in site traffic require additional investment in server hardware and bandwidth. This is a very different economic model than traditional paper-based publishers are used to. It has been the experience of the author that certain publishing houses do not currently recognise this fact. One such company contacted to obtain a textbook for the Networked Learning Environment simply multiplied the standard cost of the book by the number of medical students.

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<sup>6</sup> Data obtained from <http://www.dyerpartnership.com/rpi.html>.

- **Access**

Access to information has changed fundamentally over the centuries. Before writing was developed, information was stored (remembered) by a select group of specially trained individuals (Gaur, 1984). In order for other individuals to obtain this information, prolonged contact between these individuals and the person who held the information was required. The accuracy of the information passing between individuals was not always perfect causing the meaning to be altered as different people unintentionally re-phrased the message. Around the end of the 4th millennium BC the Sumerian and Akkadian societies reached a level of sophistication that required the accurate storage of agricultural and administrative data. To circumvent the inherent inaccuracies of a verbal society, new symbol systems were developed which could be recorded in clay. Although, borne out of a need for greater accuracy, the use of external media (clay instead of individuals) meant that for the first time information could transcend time and space. Access again is becoming an increasingly important consideration in higher education. As student numbers increase (see Section 2.2), academic libraries have to re-evaluate how many copies of each title to stock. Although short-loan collections can help ensure that most students can access a title at some point, because of rising costs there will never be a one to one ratio of books and journals to students. A solution to this problem can be through the use of electronic data-sources. Excluding the fact that an increasingly large number of students have their own computers at home, campus-based electronic access would still improve the document to student ratio to about 7 or 8:1.

- **Language**

It can be easy to simply consider media as neutral ‘containers’ of text, graphics and other symbol systems. However, even here a medium can exert a subtle force over the content it contains. For example, around 2900 BC, curved pictographic symbols used at the time abruptly changed into straight line symbols. Jean (1987) reports that the reason for this was that drawing curved lines in wet clay, a newly adopted media material, was more difficult than straight lines. Once again, as Bolter (1991) notes, the invention of printed documents permitted experienced readers to manage

600 words per minute, speeds unthinkable using ancient papyrus or medieval codex. With the increased reading of text on computer, research has found that reading speed can be slower than paper. As a consequence, Nielsen (2000) recommends reducing the amount of online text by 40% compared to a comparable paper-based text. The use of additional headings and numbered/bulleted lists are also recommended. It would appear that if the limitations of computer screens cannot be overcome quickly then the continued use of hypertext may change the long-term evolution of language permanently.

### 4.2.3 The birth of hypertext

"Electronic hypertext can be seen as the externalisation of the reading technique of an erudite person, a next step in the evolution of the written word."

(Velthoven, 1996, p. 14)

#### *Conceptual Origin*

Most researchers writing about hypertext trace its basic concept back to the Memex idea proposed by Vannevar Bush in 1945. Bush (1945) was motivated by a frustration at what he called mankind's 'ineptitude' at getting at the record (information), which he suggests was caused by the artificiality of indexing systems. He claimed that information can only be found in one place unless duplication is used, and the rules concerning indexing are 'cumbersome'. To solve this *information retrieval* problem, Bush (1945) described a theoretical machine, for it was never actually built, which he named Memex. The Memex proposal consisted of a desk with multiple viewing screens on which personal information could be displayed (books, journals, letters, notes, photographs, etc.). All formats of information would be stored using microfilm technology to provide fast access and efficient storage. However, it was not the physical characteristics of the Memex which most researchers refer to, but its methods of 'association'. Being frustrated with current indexing systems, Bush (1945) proposed a method of linking (or associating) various pieces of information with each other to form 'trails'. As an example, he suggests that to support a person investigating why Turkish short bows were more effective in the Crusades than English long bows, links could be



made between personal comments and notes, historical articles about the Crusades, and to the physical properties of different bow types. The personal library held by the Memex becomes an interrelated web of associated articles and documents.

Bush (1945) claimed that one of the main influences underpinning this new method of retrieving information was based on his observations of the way in which the human mind operates: "With one item in its grasp, it snaps instantly to the next that is suggested by the association of thoughts, in accordance with some intricate web of trails carried by the cells of the brain." (Bush, 1945, p. 106). It is the ability of the Memex, or a modern computer-supported hypertext, to support complex document structures which interests many in the potential of such a technology to support learning. The rationale being that a novice could explore and discover the structure of an expert's knowledge schema using a suitably constructed hypertext document (Liu & Reed, 1995). However, experts have counter-argued both points – that the nodes and links of hypertext resemble the human brain and that exposure to the schema of experts can enhance learning. McKendree, Reader and Hammond (1995) argue that the idea that the nodes of a hypertext network are similar to the neurones in the brain is a fallacy. They claim that although great advances in understanding the brain have occurred, we still do not understand enough to influence system design. They also reject the notion that hypertext structure is similar to the way in which semantic networks are structured. Indeed, there is not even a consensus about the structure of these semantic networks. Kellog (1995) discusses some of the theories behind three of the more important models: hierarchical representation, feature-comparison and network organization. Although Kellog acknowledges that the network organizational model is currently in vogue, Charney (1994, p. 243) asserts: "Because readers cannot import textual (or hypertextual) structures directly into long-term memory, the putative resemblance of hypertexts to long-term memory is irrelevant."

### ***Hyperreading***

Although some of the early optimism of educationalists, for a new type of device which could magically transfer knowledge directly into learners' long-term memory has evaporated, the use of hypertext in education still holds much interest. As Hammond

and Allison (1989) report, there has been a slow swing away from the behaviourist underpinnings of programmed instruction and the grander claims for Artificial Intelligence techniques. Instead, there is renewed interest in the use of technologies, such as hypertext or hypermedia, which support the newer constructivism theory of learner constructed reality. Burbules and Callister (1996, p. 31) note that, "Hypertext can allow the user the freedom to navigate courses through the material in a manner determined by his or her own interest, curiosity, and experience, or by the nature of the task at hand, rather than following a course predetermined by the author." Burbules and Callister also assert repeatedly that hypertext invites what they refer to as 'hyperreading'. But this hyperreading – the ability to jump in and out of many different texts – does not result because hypertext is non-linear and books are strictly linear, it is because of a simple quantitative change in ease of cross-referencing. Lemke (1993) posits that such a quantitative change can lead to profound changes in: scholarly communication, interactions between teachers and students, the skills of authorship, and in the very paradigm of learning itself. This view is also shared by Charney (1994, p. 239) who writes: "Hypertext has the potential to change fundamentally how we write, how we read, how we teach these skills, and even how we conceive of text itself."

Thus far, an optimistic and advantageous picture of hypertext has been painted. However, there are those who warn of its dangers. Campbell (1998) highlights the dichotomy between the rational and logical thought encouraged through traditional media and educational practices and the new 'hyperactivities' being practised. He warns:

"Thinking in Skinnerian terms, if you constantly feed someone short, instantaneous spurts of information, how soon will it be until their minds are conditioned to think in small-sized cognitive bursts, constantly seeking stimulation and entertainment?"

*Campbell (p. 26-27, 1998)*

This is the real paradox of hypertext; on the one hand small bite-sized pieces of information enable a large number of links to be placed between them, allowing readers to explore domains from many different perspectives, but on the other hand hypertext is limited in the complexity of its arguments because of the need for each node to be self-

contained. Few complex sequences guiding the user through a topic are constructed because of the need to insert links at many different places along the sequence. Thus, nodes have to be simplified so that if a reader jumps from node A to node C (assuming they are related in some way) then he or she is not required to have first read node B.

Currently most of the data gathered about the educational potential of hypertext has concerned short-term usability. These have typically been laboratory-based measures of subjects' attitudes, navigational patterns and performance. Because of practical experimental difficulties, longitudinal studies are less frequently attempted. However, it is these which are needed to establish whether the practical ease of information exploration and handling outweigh the disadvantages of the hyperactive mind discussed by Campbell (1998).

#### 4.2.4 Summary

As stated earlier, Robertson (1998) argues that to a certain degree civilisation is information. Although somewhat of a simplification, this assertion has support from Gaur (1984) who argues for an alternative method of covering literary history:

"There is in fact no essential difference between prehistoric rock paintings, memory aids (mnemonic devices), wintercounts, tallies, knotted cords, pictographic, syllabic and consonantal scripts, or the alphabet. There are no primitive scripts, no forerunners of writing, no transitional scripts as such (terms frequently used in books dealing with the history of writing), but only societies at a particular level of economic and social development using certain forms of information storage."

*(Gaur, 1984, p. 14)*

Hypertext is not generating interest simply because it is a novel application of computers, although originally this might have been the case, but because it appears to offer a number of advantages compared with paper for representing and manipulating information. Four themes appear to dominate the evolution of literature – a reduction in cost, increased accuracy, increased access speeds (temporal, spatial, socially), and an



increase in the quantity of information represented. Hypertext appears to be the next logical step in the evolution of literature by advancing each one of these themes. Cost is reduced and will continue to fall dramatically because of Moore's Law (1965). Information can also be more accurate when accessed in hypertext format. Although the spelling is no more accurate than books, it could be argued that hypertext can more accurately capture the true semantics of a particular knowledge domain. Utilising sophisticated referential linking systems together with the powerful interplay of textual, graphical, audio and video formats, hypertext can store a more 'direct' representation of a given topic. Access levels an order of magnitude greater than books can be achieved using powerful file servers capable of handling thousands of client machines spread over a wide geographic area. Finally, almost as a direct consequence of the other three themes, the amount of information that can be accessed using hypertext will be greater than all previous literary media.

### 4.3 The anatomy of modern hypertext

“Hypertext is a term now applied so widely that it is no longer clear that it means anything other than the ability to retrieve information rapidly and relevantly by direct selection.”

(Mayes, Kibby, & Anderson, 1990a)

A cursory glance at the wide range of software labelled hypertext will probably suggest that there are few shared features. What is the connection between MS Word, the World Wide Web, Perseus and the Oxford English Dictionary? Many academic papers pay only lip service to defining hypertext in their introductions. Most mention the ability to read documents in a *non-linear* way by navigating various *link* paths between *nodes*. However, before beginning to design or select an existing system, it is necessary to understand in more detail the breadth of hypertext functionality. Gall and Hannafin (1994) present a framework with which to clarify the varied functionality associated with hypertext. This framework, shown in Table 4.1, contains three main categories: macro-level structures, micro-level structures and control structures.

Macro-level structures	Knowledge base	Can be described relatively in terms of breadth, depth, homogeneity, and connectedness
	Interface	Composed of presentation, learner response, and feedback
	Navigation	Includes adjacent, distant, and semantic jumps
Micro-level structures	Nodes	Can be presentation, dynamic presentation, or interaction
	Links	Described as hierarchical, conceptual, or referential
Control structures	Searching	Process – seeking a particular piece of information Product – 'hit' or 'miss'
	Browsing	Process – pursuing information without a specific need Product – trail of viewed information
	Connecting	Process – creating links between pieces of information Product – newly created link
	Collecting	Process – assembling information apart from the system Product – information in a new format

Table 4.1 Hypertext system structures and functions (from Gall & Hannafin, 1994, p. 210).

The first level is what Gall and Hannafin (1994) refer to as the 'macro-level structure'. This is present in all hypertext systems and includes fundamental components and functionality such as a knowledge base, the user interface and a set of navigational capabilities. At a more detailed level there are 'micro-level structures' which comprise the nodes (see Section 4.4.4) and links (see Section 4.4.5) of a hypertext system. Finally, the framework includes a number of 'control structures', facilities which allow the user to perform certain tasks using the hypertext. Gall and Hannafin (1994) include four control structures: searching, browsing, connecting and collecting. However, Norman (1994) argues for the inclusion of 'planning' facilities. These five concepts will be discussed further in Sections 4.4.6 to 4.4.10.

### **4.3.1 Knowledge Base**

All hypertext systems, regardless of presentational format (text, graphics, sound), store and make available to the user information on various topics. Gall and Hannafin (1994) suggest that it is possible to describe a knowledge base in terms of its breadth, depth, internal consistency and connectedness of the concepts it contains. Although they do not specify how to actually measure these dimensions, indeed it is likely that any quantitative assessment between disparate domains would be very difficult, these terms are still useful in that they can provide additional information as to when hypertext might be a suitable educational vehicle. Jacobson and Spiro (1994) also discuss various dimensions of a knowledge base and conclude that different knowledge domain characteristics, and importantly different stages of learning, require alternative forms of computer-assisted learning. Hypertext moves then from the all encompassing panacea which some of its strongest advocates suggest to being another tool in the educational armoury.

- **Breadth**

The breadth of a knowledge base is the relative measure of the diversity of its subject matter. Dictionaries and encyclopaedias are examples of knowledge bases

with wide breadth. There is often a loose relationship between breadth and depth. For example, an encyclopaedia covers many topics but in not much detail, whereas a specialist medical document on auditory diseases has much greater detail but on fewer topics (those related to the ear only).

- **Depth**

Depth refers both to the *amount* and *complexity* of the knowledge base. As stated above, often when the scope of a knowledge base is narrower more depth is provided. Complexity refers to how many concepts must be understood with reference to the main subject matter under investigation (Jacobson & Spiro, 1994). The domain 'Global Warming', for example, is a complex domain because it requires an understanding of the related domains of chemistry, meteorology, oceanography, physical and social geography, and possibly tropical diseases.

- **Internal Consistency**

Internal consistency is a measure of the similarity-dissimilarity of the knowledge base. Gall and Hannafin (1994) use computer databases as examples of knowledge bases which are quite homogeneous, and contrast them to the heterogeneous information a scrapbook can contain (newspaper clippings, old report cards, postcards, photographs, etc.). Hypertext can easily be used to store either homogeneous or heterogeneous information, but it has particular strength in representing a wide range of different information formats. For example, few other media can present through a single interface text, graphics, video, audio and interaction (e.g. VRML microworlds).

- **Structuredness**

The 'structuredness' continuum runs from well-structured to ill-structured. Well-structured domains possess a regularity in structure which allows rules or principles to be abstracted (e.g. arithmetic, Newtonian physics). Prototype examples can also be developed which closely match real-world case situations. Conversely, ill-structured domains are defined as having a wide number of related concepts but their use varies widely across different case situations (e.g. literary interpretation,

history, biomedicine). Although this well- to ill-structured continuum appears simple, Jacobson and Spiro (1994) do highlight two important phenomena. Often domains that are well-structured, such as engineering, must be applied in highly ill-structured real-world situations. Also, domains that are well-structured at elementary to intermediate-advanced levels frequently assume the characteristics of ill-structuredness at the 'cutting-edge' of the field (e.g. chaos theory).

- **Connectedness**

Connectedness refers to the number of associations made between different concepts within the knowledge base. A fictional novel contains no associations, they are purely linear in their exposition (even flashback episodes). At the other end of the connectedness spectrum lies the Concise Oxford English Dictionary on CD-ROM. Every word forming a definition may be clicked to bring up its own definition.

### 4.3.2 Interface

#### *Embedded menus*

In most applications there is a workspace which is controlled using a separate menu system. However, in most hypertext implementations *embedded* menus are used in addition to *explicit* menu systems (e.g. pulldown menus). Embedded menus are information entities (i.e. text, graphics, video) which as well as conveying information, represent selectable actions (normally a link activation). Balasubramanian (1994) quotes the following advantages of embedded menus:

- They highlight semantic relationships rather than physical relationships.
- They provide meaningful task domain terms (as opposed to computer domain terms) and concepts, thereby reducing disorientation.
- They reduce the 'loss of context' feeling by being part of the information being displayed.



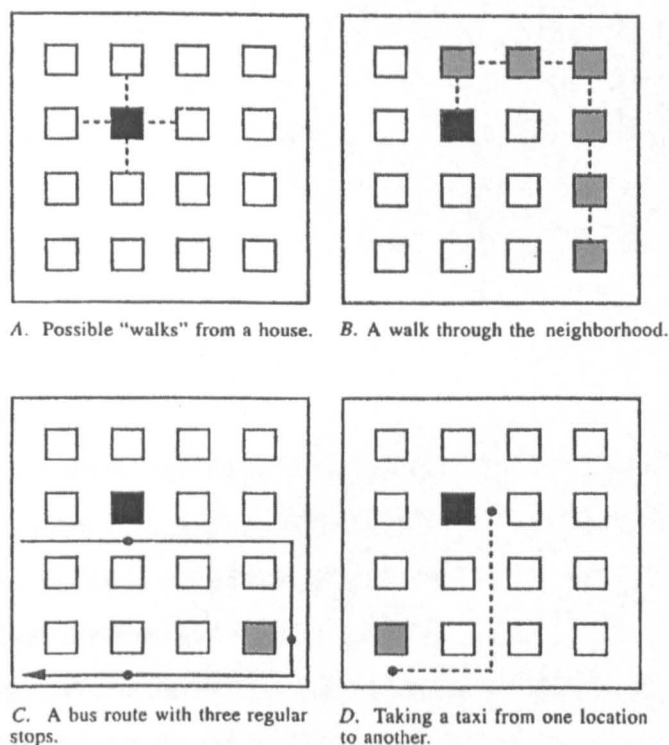
Indeed, in an empirical study, Vora, Helander and Shalin (1994) found that users performed 26% faster using embedded menus rather than explicit menus in a hypertext system. However, as Balasubramanian (1994) notes, embedded menus may disrupt the reading process (and thus speed) and might affect comprehension. Literature on this particular aspect of embedded menus is rare and further research would undoubtedly be useful.

### **Windows**

Based on the pioneering work of Doug Engelbart in the 1960s, windows were developed as a mechanism to provide independently controllable sections of a screen. Commonly windows are used by multitasking operating systems to 'contain' separately running processes. For example, a user could have a word processing document loaded in one window and a spreadsheet in another window. Although, it is possible for the user to visually compare the contents of two windows, in practice the low resolutions of computer screens makes it difficult to effectively manage a large number of independent windows. As will be mentioned later in Section 4.6.4, O'Hara and Sellen (1997) found that whereas subjects using paper could spatially arrange individual sheets with ease, word processing users had difficulty in displaying multiple documents simultaneously. This issue will be returned to again in Section 9.4 which discusses possible future workstations involving multiple display monitors.

### **4.3.3 Navigation**

In addition to a knowledge base and suitable interface, the third macro-level structure available in all hypertext systems is *navigation*. This generic term is used to describe user behaviours when trying to locate information within a hypertext knowledge base. Importantly, Gall and Hannafin (1994, p. 213) note: "Although all data in a hypertext system are theoretically *addressable*, they are rarely equally *accessible*." They go on to discuss some of the more common navigational methods using a neighbourhood metaphor which can be seen in Figure 4.1.



**Figure 4.1** 'Neighborhood' metaphor for hypertext linking options (from Gall & Hannafin, 1994, p. 214).

Three main forms of navigation can be found in this metaphor:

### 1. Adjacent jumps

Adjacent jumps function like a pedestrian walking from their current location to a neighbouring house as shown by the dotted lines in Figure 4.1A. Navigation is simple when the distance between the user's current location and the desired information is small, but problems can occur over larger distances. Figure 4.1B shows a longer journey where the user must traverse six links to reach the desired node. Gall and Hannafin (1994) argue that hypertext navigation could become very tedious if limited to adjacent jumps. Examples of adjacent jumps include the 'previous' and 'next' buttons in Windows help systems.

### 2. Distance jumps

Distance jumps function like a bus which operates on pre-defined 'routes' between non-adjacent locations, such as is represented in Figure 4.1C. While such

navigation is more efficient for longer journeys than walking past every node on the way, the user does need to know which bus to catch, where it leaves from and what its destination is. This form of navigation becomes inefficient when the user knows where they want to go, the train station for example, but not exactly how to get there. Trying all possible bus routes throughout the city would require much time and expense.

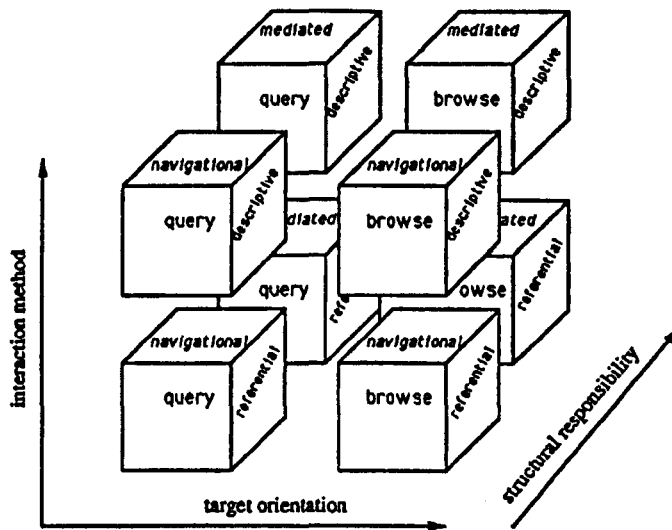
### **3. Semantic jumps**

A solution to the above situation, where the user knows the destination but not the route, is to use semantic jumps. Continuing with Gall and Hannafin's neighborhood metaphor this is similar to instructing a taxi driver, see Figure 4.1D, to drive to a specific location without knowing or possibly caring what route is chosen. To achieve this type of movement through a hyperspace many systems employ search routines. Although these do differ in terms of functionality, the basis of any search engine is a results set presented to the user (alphabetically, ranked, etc.) which allows them to select a destination node of interest without requiring any knowledge of the hypertext structure between the current and destination nodes. The disadvantage of semantic jumps is when a search returns either too few or too many hits.

While Gall and Hannafin's (1994) neighbourhood metaphor emphasises the importance of distance within hypertext knowledge bases, Waterworth and Chignell (1991) present a more analytical approach to navigation. Arguing that current notions of browsing and querying are limited, and terms such as 'navigate' and 'browse' are used synonymously, Waterworth and Chignell (1991) introduce the phrase 'information exploration'. The advantage of such a rephrasing of the common terms used to describe 'navigating' is that it can be used to describe finding information in any electronic environment. In this manner databases only lie at a different position on the same information exploration continuum that hypertext lies on. Indeed, Stotts and Furuta (1991) speculate about the separate futures of the fields of databases and hypertext. They conclude that although the implementation mechanisms and user facilities may be similar, the two fields will

remain distinct due to a primary division in the users' tasks: intentional uses versus undirected browsing.

At the heart of Waterworth and Chignell's (1991) notion of information exploration lie three orthogonal dimensions which can describe information seeking behaviour. The various possibilities available using these three dimensions, structural responsibility, target orientation, and interaction method, can be seen visualised in Figure 4.2.



**Figure 4.2** 3D model of information exploration (from Waterworth & Chignell, 1991, p. 38)

- **Structural responsibility**

The first dimension, structural responsibility, deals with which agent is responsible for carrying out an information search. For example, when navigating it is necessary that the user understands the structure of the underlying knowledge base. Conversely, when running a query it is the system which must understand the structure of the hyperspace.

- **Target orientation**

Often in the hypertext literature it is naively assumed that browsing involves using hypertext links while querying involves the use of some sort of search engine. Instead, Waterworth and Chignell (1991) define browsing and querying on a continuum running from an indefinite target or goal of the user to a very definite

target. Thus, as they state, the terms browsing and querying are not determined by what facilities the user operates, but, in fact, by the cognitive state of the user.

- **Interaction Method**

The third dimension refers to the form of interaction used to explore the information space. Waterworth and Chignell (1991) suggest that an important distinction can be found between *descriptive interfaces*, where the user describes what is wanted, and *referential interfaces*, where the user can select what is wanted. While the authors acknowledge that descriptive interfaces have usually been associated with querying and referential interfaces with browsing, they point out that there is no intrinsic correlation between interaction method and target orientation or structural responsibility.

The precise mechanisms provided by modern hypertext systems to support browsing will be discussed in Section 4.4.6 and querying (or searching) will be discussed in Section 4.4.7. After reviewing Waterworth and Chignell's distinction between browsing and querying it becomes obvious as to why there are a wide range of different tools and facilities to support browsing. When querying, the software knows precisely the underlying data structure, but a user engaged in browsing does not know the exact structure developed by the author. Thus, all the browsing tools are designed either to elicit the author's structure or to provide information to the user about their current interaction session with the goal of minimizing disorientation.

#### **4.3.4 Nodes**

Nodes are the conceptual unit of hypertext 'pages'. Although it is reasonable to think of database records as possible nodes, the reverse analogy is not entirely accurate. Hypertext nodes differ from records in two important respects: 1) nodes do not need to share a common structure (i.e. not constrained by fields), and 2) the size of a node within a single hypertext can differ widely whereas all records in the same database table contain the same number of fields. While databases allow complex querying and

data checking (referential integrity, validation) to be performed, ultimately their rigid structure limits their application. On the other hand hypertext can be used to store *any* type and *any* amount of information.

The amount of information that should be stored within one hypertext node has been the subject of several studies. Kim and Eastman (1999) argue that the concept of node size has not been well defined. They suggest that node size can be defined in three main ways: 1) *physical size* – the amount of storage space required, 2) *presentation size* – window or screen size used to visually display the node, and 3) *logical size* – the length of the node as presented to the user. Some hypertext systems, such as HyperCard, require the logical size to be the same as the presentation size. It is simple to design hypertext documents in such systems when the logical size is less than or equal to the presentation size, but solutions have to be found to display larger logically sized nodes. Two main solutions have been used to display larger logical nodes: 1) physical pagination of the node, or 2) the use of window scrolling mechanisms. The former approach is often used in HyperCard stacks (Kim & Eastman, 1999; Shapiro, 1998), Hyperties systems (Furuta, Plaisant & Shneiderman, 1989) and KMS. The scrolling approach is adopted by WinHelp, Netscape Navigator and MS Internet Explorer web browsers, DynaText, and Adobe Acrobat. Neither solution is entirely satisfactory. Piolat, Roussey and Thunin (1997) found that non-scrolling nodes provide important spatial cues which benefit both readers and authors. Such spatial cues are lost with scrolling displays. However, in an experiment conducted by Kim and Eastman (1999), information retrieval times were significantly faster in larger scrolling nodes rather than smaller screen-formatted nodes.

Conceptually, the structure of screen-based nodes appears somewhat at odds with the philosophy of hypertext; the user who has traversed hierarchical and web-based networks to arrive at the current node is then forced into a purely linear exploration of the local material. Problems also occur when rendering the display of presentation-based nodes. For example, static HyperCard stack sizes work well when the screen size of the underlying Apple Macintosh platform is relatively homogenous. However, the visual display market is rapidly diversifying, now ranging from small palmtop and even

mobile phone displays through to very large plasma monitors and multi-monitor based workstations. A hypertext document implementing presentational node sizes would have to re-paginate ('screeninate') each time the system detected different display hardware. The difficulties of controlling effective line length/spacing, graphic sizes and overall layout positions would be immense.

*Node Typing*

A large number of hypertext systems, including the World Wide Web, employ untyped, or generic, node types and link types. One of the problems associated with generic types, Rao and Turoff (1990) claim, is that as the size of a hypertext system grows, the meanings assigned to nodes and links become ambiguous. To resolve this problem they studied a number of theories of intelligence and then selected Guildford's Structure of the Intellect with which to form a general hypertext framework. Balasubramanian and Turoff (1995) argue that using such a framework every type of human cognition (nodes) and mental relationships (links) can be mapped onto it. The node types suggested by Rao and Turoff (1990) can be seen in Table 4.2 below.

Guildford (Cognition)	Hypertext (Nodes)	Related Terms
Units	Detail	Definition, reference, fact, support
Classes	Collection	Set, group, gathering, aggregation, conglomeration
Relations	Proposition	Analogy, model, law, theorem, belief, axiom, proposition, assumption
Systems	Summary	Generalization, system-template, overview
Transformation	Issue	Question, concern
Implications	Observation	Action, policy, decision, observation, conclusion, recommendation

**Table 4.2** Node types based on Guildford's forms of cognition (Rao & Turoff, 1990).

*Dynamic Node Content*

So far, the current description of nodes has been limited to fixed or static node content. That is, the information contained within a node, with the slight exception of temporal data formats, remains the same between visits to the same node – just as the text on a printed page does not change. However, a number of studies have investigated the

benefit of actually altering the content of a node to better suite the needs of the user at different times. Boyle (1994) discusses an adaptive hypertext system called *Metadoc*. The system works, like many adaptive systems, by using an intelligent agent which monitors the user's interaction and constructs a user model. This model is then used to determine the most suitable node content to be delivered. The knowledge domain used by Boyle (1994) to evaluate Metadoc was a technical manual concerning management of the AIX operating system. The user model contained novice, beginner, intermediate and expert stereotypes for each person using the system. The system then used this information to alter the type of information displayed to the user for each part of the AIX manual. For example, users with less knowledge were provided with more *explanations* (definitions of key vocabulary, simpler and less technical versions, more examples, and supplementary background information), while users with greater knowledge were given greater *detail* (lower-level concepts in the concept hierarchy). If the user requested further explanations or greater detail then the intelligent agent updated the user model which would then alter possible future node presentations. The results of an empirical test comparing Metadoc to a traditional 'unintelligent' hypertext system revealed that both novice and expert subjects spent significantly less time reading in the Metadoc condition and scored significantly higher marks on a reading comprehension test than subjects who used the non-adaptive hypertext.

A second dynamic hypermedia system is discussed by Carver, Howard and Lane (1999). This time, instead of focussing on the individual difference of knowledge level, Carver, Howard and Lane (1999) studied how a hypertext system could adapt to alternative learning styles. Using an online set of 28 questions, users were categorised on three orthogonal learning style dimensions: 1) sensing/intuitive, 2) visual/verbal, and 3) sequential/global. After this user model is constructed, the system determines the most appropriate content by using a media lookup table. The table consists of a list of the various tools available in the system, a list of the learning styles and a matrix of numeric weightings which can be seen in Table 4.3 below. When a node is retrieved the user's learning profile is retrieved from the user model and used to rank order (most appropriate first) the available learning tools (media) for the current topic.



Tools/Style	Sensing	Intuitive	Visual	Verbal	Sequential	Global
Hypertext	25	60	25	25	100	40
Slideshow	50	40	70	50	70	60
Audio	60	50	25	100	10	60
Graphics	70	50	90	25	10	40
Movies	100	50	100	80	40	30
External Programs	60	25	10	10	10	25
Student Response System	10	50	25	10	60	80
Virtual Computer	100	25	90	70	60	80
Course Legacy System	50	50	60	10	25	90

**Table 4.3** Media tools and their relationship to learning styles (from Carver, Howard & Lane, 1999, p. 37)

Carver, Howard and Lane (1999) report that instructors teaching on CS383 Computer Systems course which utilised the adaptive hypermedia system noticed that students appeared to be learning more material at a deeper level. Several other important changes were noticed. For example, the instructors were seen more as facilitators of learning instead of ‘master of all knowledge’. Also, the amount of additional instruction students requested outside the classroom was significantly reduced by access to the wide range of informational resources in the hypermedia system. Unfortunately, though, while the performance of the best students increased substantially, the performance of the weakest students actually declined. Carver, Howard and Lane (1999) do not provide any explanation as to why the weaker students performed worse with the tailored instruction. The question remains, does the tool/style lookup table require adjusting or is there a more inherent disadvantage of using hypertext with weaker students?

**4.3.5 Links**

Whereas nodes represent concepts, it is the links which represent the relationships between these concepts. It is these links which are used to describe the advantages of hypertext over traditional forms of literature. For example, Cunningham, Duffy and Knuth (1993, pp. 32-33) write:

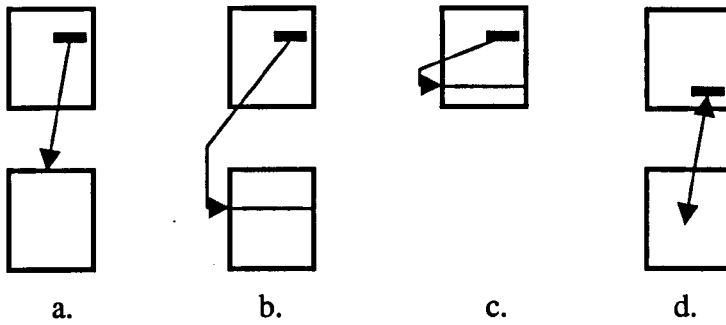
"The important distinction between hypermedia and a textbook is that the hypermedia environment relieves the requirements of a linear presentation. While we do not see books as necessarily being used as linear documents, the linear format certainly constrains the writer to a cohesive, integrated presentation."

Hypertext is not a revolutionary technology. As Cunningham, Duffy and Knuth acknowledge, books can be used in non-linear ways using cross-references and footnotes. Instead, hypertext is at the current pinnacle of literary evolution – facilitating new forms of non-linear information exploration (Lemke, 1993). It is the links that are special in hypertext; nodes of information can be stored in many different ways (e.g. databases), but few media are capable of the sophisticated link structures found in modern hypertext. Links<sup>7</sup> were also at the heart of Bush's (1945) argument. When a piece of information is indexed it can only be in one place at a time, unless duplication is used, and the user must understand the indexing mechanism (alphabetical, chronological, etc.) in order to find the required material. However, Bush observed that the human mind does not operate in this manner, it operates by association. Thus, he proposed a machine that could store and retrieve records based on this principle of association. These associations are similar to links in current hypertext.

All links require at least two properties, a *anchor* point and an *end* point (Vaughan, 1994). The anchor and end link points usually exist in different nodes (see a, b and d in Figure 4.3), however intra-node links (see c in Figure 4.3) are available in some hypertext systems (e.g. Adobe Acrobat, HTML, WinHelp).

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<sup>7</sup> More precisely sets of links forming what Bush (1945) referred to as trails.



**Figure 4.3** Basic link mechanisms: a) link points to a whole node, b) link points to a specific location in a different node, c) link points to a specific location in the same node, and d) link is bi-directional.

Once the anchor and end points of a links are calculated, the designer then faces the problem of how to signal to the user the presence of the link. The visual design of such link cues can effect the user's perceptions of the existence and purpose of a link, or the contents of the destination (Carlson and Kacmar, 1999). In order to maximise the usability of link markers they suggest the following guidelines:

1. Make the user aware of all available links
2. Indicate precisely which objects or nodes are associated with a link, *both* at the source and destination ends of the link
3. Do not interfere with the user's interpretation of the information contained within the node

To test these guidelines Carlson and Kacmar (1999) conducted a series of experiments to access their utility. Link types used in the experiments included: colour, italic, box, bullet, shading, characters and glyph. Results indicated that colour was perceived by users to be the most effective way of identifying a link marker. Least effective was found to be character cues that used various letters to surround the link text (e.g. '<>', '{}', or '[]'). Bounded link markers were also found to be better than non-bounded markers. Bounded markers (e.g. colour, italic, shading, characters) show exactly which words form the link, whereas non-bounded markers only show the beginning of the link words. Interestingly, Carlson and Kacmar (1999) found that link marker preferences

changed when non-standard links were used. Example of non-standard links include non-standard navigation or activity (e.g. spawning a new process or applet, opening a new window, providing a menu of navigation choices).

Although user preferences for various link markers may differ, the problem of cueing their presence is not a difficult one. However, for blind or partially sighted users being able to know which pieces of information forms which links can be problematic. For example, a node can contain multiple links which can be easily *viewed* simultaneously, but if the same node is *spoken* using screen reader technology then there is a temporal ordering of links. The solution to this problem proposed by Petrie, Morley, McNally, O'Neill and Majoe (1997) is the creation of a *current* link, that is a link which is read out becomes the current link until the next link is reached. Pressing a 'select' button at any time initiates the current link. To signify that an object is a link and not a normal piece of information, Petrie *et al.* suggest three possible cueing mechanisms: 1) earcons which play before (and possibly after) the link anchor, 2) alteration in the tone of the voice for pronouncing links, or 3) saying the word 'link' before and after the appropriate word(s).

### ***Link Types***

Thus far the basic purpose of a link has been discussed and how its presence can be communicated to the user. These links, with the exception of the bi-directional links shown in Figure 4.3, have been simple uni-directional links. The only information they provide to users is the link anchor point (on the current node) and possibly where the link might lead through a button, graphic or piece of text. However, as already discussed in Section 4.4.4, Rao and Turoff (1990) developed a hypertext framework based on Guildford's structure of the intellect model. Two primary link types emerge from this framework: convergent link types shown in Table 4.4 and divergent link types shown in Table 4.5. Rao and Turoff describe convergent links as relationships between nodes that are singular, clear, primary in nature, and are productive in narrowing or focusing the overall pattern of relationships. Conversely, divergent links represent relationships which are not part of a clear path or sequence and expand and broaden the pattern of consideration.

<b>Guildford (Convergent Production)</b>	<b>Hypertext (Convergent Links)</b>	<b>Related Terms</b>
Precision	Specification	Fact, definition, keyword, index
Names	Membership	Parent-child, subset, tree-links
Correlates	Association	Similarity, concurrence, correlation, equivalence
Order	Path	Sequence, chapter, document, list, trail
Changes	Alternative	Conflict, con, option, choice, disagreement
Conclusion	Inference	Influence, cause-effect, evidence, support, Implication, deduction, induction

**Table 4.4** Convergent link types based on Guildford's forms of convergent production (Rao & Turoff, 1990).

<b>Guildford (Divergent Production)</b>	<b>Hypertext (Divergent Links)</b>	<b>Related Terms</b>
Detail	Elaboration	Reference, footnote, fact
Antithesis	Opposition	Contradiction, converse, inverse, reverse
Expressions	Tentative	Speculation, conjecture, emotional, artistic
Divergence	Branch	Fork
Shift/Novelty	Lateral	Deviation, alter, creative
Ideas	Extrapolation	Goals, objectives, norms, values, beliefs

**Table 4.5** Divergent link types based on Guildford's forms of divergent production (Rao & Turoff, 1990).

With six node types and twelve link types in total, problems of user interface design may occur. For example, how can the node and link type information be relayed to the user. The approach taken by Balasubramanian and Turoff (1995) was to use a map displaying nodes as rectangles linked together by lines representing the links. Small labels next to each node and link then represent the type as a two letter abbreviation. Of course since abbreviations are used a key is required to remind users the full meaning. The disadvantage of this is that the key itself takes up valuable screen space and so thus reduces the overall amount of detail that can be included in the map. Unfortunately Balasubramanian and Turoff (1995) do not specify how links embedded in the text would appear. These would need to convey both the type of the link and the type of the destination node. Another criticism of this work is that neither the Rao and Turoff

(1990) paper nor the Balasubramanian and Turoff (1995) paper present any empirical data showing the advantage of their typed nodes and links. Although their framework maps onto Guildford's structure of the intellect, there is no evidence to show whether the resulting hypertext systems in practice would reduce the problems of disorientation and cognitive overhead.

### ***Manual vs. Automatic link generation***

One of the problems of manually authoring hypertext links is in their maintenance and debugging. Just as the 'Goto' command in various computer languages made understanding the logic of programs difficult, the similar hypertext goto pointer, the link, makes hypertext authoring difficult. Most people who have navigated through the World Wide Web will be familiar with the 'Error 404 file not found' error message. Such problems occur when a link points to a non-existent node, the equivalent to a dangling-pointer in data-structures. With some hypertext systems containing more than 5 million nodes, for example the Library of Congress and NASA archives (Shneiderman, 1997), ensuring the links between these nodes are correct constitutes a major systems development problem. Some hypertext authoring systems, such as the Windows Help Compiler Workshop, automatically check all link destinations when a hypertext system is constructed (compiled). However, such a task is easy to complete on a singular hypertext but infinitely harder on a collaboratively authored and distributed hypertext environment such as the WWW. Utilities do exist that will scan an HTML page for links and then verify their destinations, but this still cannot prevent problems when an author actually removes content which is pointed to by other pages.

To avoid the maintenance problems associated with manually created links, automatic insertion can be used. However, as Furuta, Plaisant and Shneiderman (1989) note, converting paper-based texts into hypertext using automatic techniques can still be problematic. For example, recognising the logical structure of a document without special markup remains an important problem. Identification of specific parts of a document, for example headings, can be automated by pattern matching techniques. However, even here Furuta *et al.* warn that headings that can appear similar visually can

be subtly different, resulting in incorrect pattern matching. They suggest that close human monitoring of such a conversion process is still required.

A second solution to the authoring problem of links is to create a hypertext system without any links. Golovchinsky (1993) effectively proposes such a system with his Queries-R-Links prototype. Instead of specific links stored within the hypertext, the system allows users to interactively create links as and when required. To 'link' from one node to another the user highlights a word of interest on the currently displayed node. After searching through the hyperspace for other nodes containing this word the system presents a list of matches. To traverse the link the user simply selects the name of one of the matching nodes.

### ***Link Structures***

Unlike book structures which are determined by the physical binding of *pages*, the structure of hypertext systems are dependent upon the patterns of *links* established between nodes. Although it is possible in hypertext to create links between any two nodes in a system, various broad link structure types can be identified. As Figure 4.4 below shows, six main structural types can be identified:

- **Linear**

Either all nodes are connected together in a single sequential structure, or as in Figure 4.4, separate linear structures are created for the three main topics covered by the hypertext.

- **Conceptual**

Conceptual node structures are formed when there are a number of subordinate nodes which elaborate or otherwise enhance a central node.

- **Hierarchical**

Each node in a hierarchical link structure defines precisely its sub- and super-ordinate relationships with other nodes.

- **Hierarchical and Nonlinear Combined**

Hierarchical and nonlinear combination structures can be created by imposing, firstly, an overall hierarchical framework over the whole hyperspace and then inserting additional nonlinear associative links.

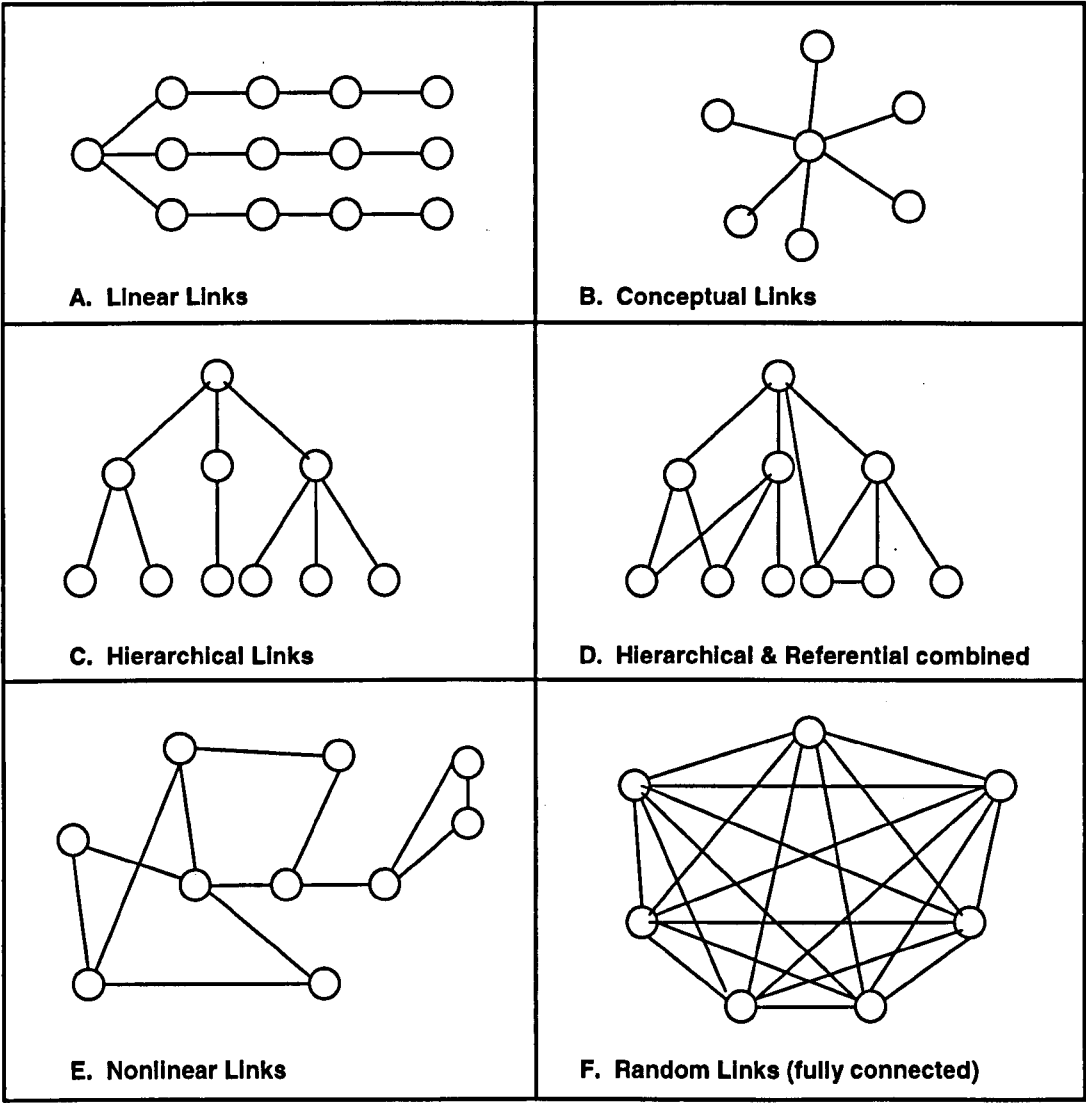
- **Nonlinear**

Nonlinear structures are hypertext systems which use multiple links that do not embody linear or hierarchical relationships.

- **Random**

All the structure types discussed so far have all utilised links which represent meaningful relationships between nodes. For the sake of completeness, this link structure taxonomy can be completed by the inclusion of a final random structure. The structure shown in Figure 4.4f shows a fully connected hyperspace where every node links to every other node. Some links might be meaningful but others may not.





**Figure 4.4** Main hypertext link structures reported in the literature.

Empirical evaluation of various link structure shows that not all are equally effective in terms of ease of navigation. Mohageg (1992) compared four different hypertext structures: linear, hierarchical, network & combination (hierarchical and network topology – example D in Figure 4.4). In terms of search time, users assigned to linear structure took significantly longer than the other structures, and the combination structure resulted in significantly shorter task completion times than the network structure. No significant task completion differences were found between the hierarchical and combination structures.

In contrast to the Mohageg (1992) study, McDonald and Stevenson (1996) found that the linear structure resulted in the quickest task completion times. McDonald and Stevenson evaluated linear, hierarchy and non-linear versions of a 45 node hypertext. They employed two separate tasks to do this: the first involved answering ten questions and then a second task, following a distraction event, involved locating five different nodes. The result of the first question answering task was that subjects assigned to the linear structure were significantly faster (75.63 seconds) than those assigned to the hierarchical structure (86.19 seconds) which in turn were significantly faster than the non-linear subjects (100.62 seconds). McDonald and Stevenson (1996) also calculated the mean number of additional nodes opened for each condition. This was calculated by subtracting the number of cards opened by the subjects from the optimal number required for each question. The result was 1.2 extra nodes for the linear structure, 7.8 extra nodes for the hierarchical structure, and 11.3 extra nodes for the non-linear structure. Similar patterns, in terms of speed and optimal route, were discovered for the various structure types on the second node location task. An interesting question from an educational perspective, is, should all students follow tightly the optimal path to answer a question, or find some knowledge along the way? Serendipitous discovery of new material is often quoted as one of the advantages of hypertext over alternative forms of education. Using this as a new basis for evaluation, it would appear from the McDonald and Stevenson (1996) study that the network structure would be most suitable in promoting serendipitous discovery.

A more recent study by McDonald and Stevenson (1998) utilised hierarchical, combination and nonlinear hypertext link structures. Again a hypertext size of 45 nodes was used and two tasks were separated by a distraction test. Subjects assigned to the hierarchical and combination structures completed the tasks significantly faster than those subjects assigned to the nonlinear structure. In addition, on the second task, subjects using the combination version performed significantly faster than subjects in the hierarchical structure. McDonald and Stevenson (1998), as in their 1996 study, calculated the mean number of additional nodes opened during each task. The pattern again followed closely the task completion times. The fastest version (combination structure) accessed fewest additional nodes followed by the hierarchical structure and

finally the nonlinear structure. It would appear that the close correlation between the time it takes to complete the set tasks and the number of addition nodes opened is due to the fact that more time is required to open additional nodes and vice versa.

#### 4.3.6 Navigating

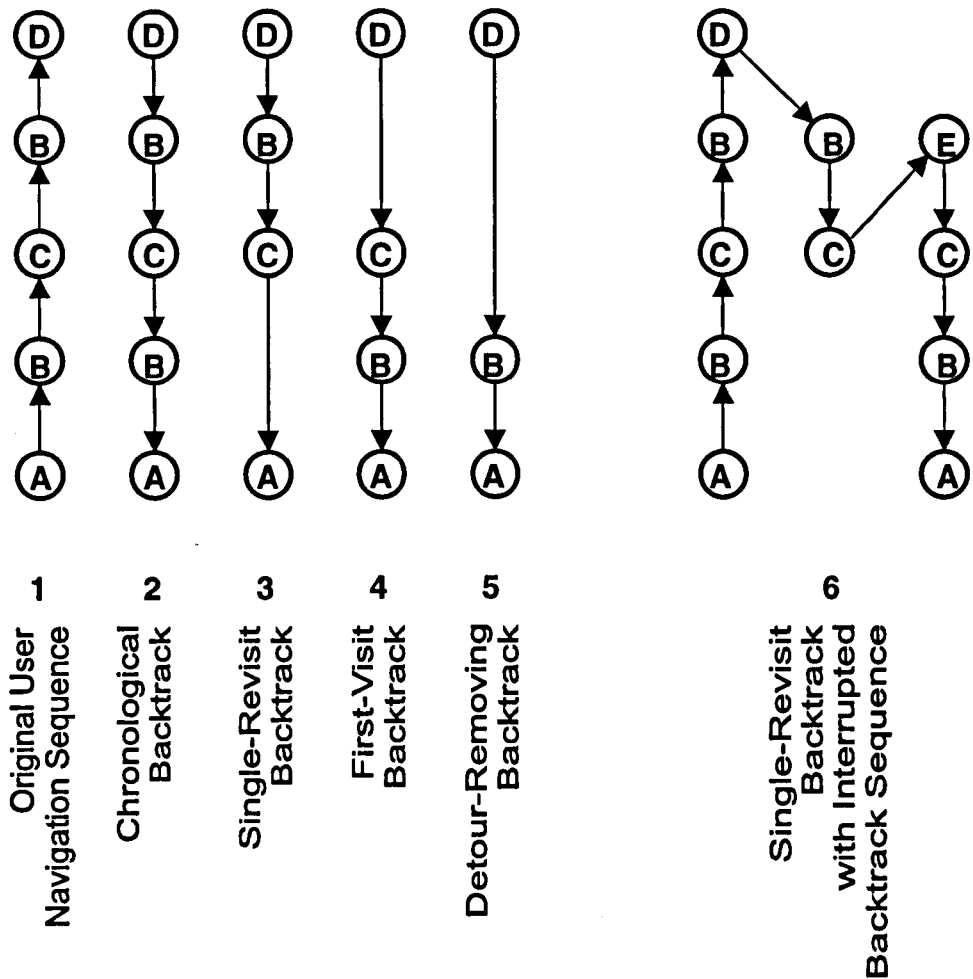
As already discussed in Section 4.3.3, the structural responsibility involved in navigational information exploration falls on the user. As a consequence a number of different navigational tools have been developed to help users plan a route to the information they require (e.g. tables of contents, indexes, diagrams) and to enable the user to maintain a sense of location within large hyperspaces (e.g. history lists, footprints). A brief description of the more common tools is presented below to give a sense of the wide range of hypertext navigational aids.

##### *Backtracking*

Backtracking, or Audit Trails as they are also known, are one of the most important hypertext navigation facilities (Nielsen, 1995). However, there is some contention as to the best way to implement backtracking functionality. For example, Velthoven (1996) describes some of the challenges and solutions experienced by the design team creating a multimedia CD-ROM product called *Doors of Perception 1*. One of the issues debated by the team was provision of backtracking. The team, Velthoven (1996) reports, at the beginning, were under the impression that all users would know the information structure of the CD-ROM and so would not require any form of backtracking. However, this *systems thinking* view is not the same as the *operational* view of the user. Thus, after some user testing, a single step backtracking facility was added.

Although the *Doors of Perception 1* system used a single level backtrack, similar to a simple 'Undo' command, many hypertext systems employ multi-step backtracking (e.g. WinHelp, WWW Browsers, Adobe Acrobat). Returning one step to the previously visited node is quite a simple procedure, but backtracking multiple steps becomes a

more complicated process. Nielsen (1995) discusses five different types of backtracking mechanisms which are shown in Figure 4.5.



**Figure 4.5** Various backtrack models. Sequence 1 represents the user's initial navigation and sequences 2-5 represent possible backtrack movement. Sequence 6 shows a more complicated example of sequence 2. (From Nielsen, 1995, p. 250).

Column 1 in Figure 4.5 represents the user's original path through the hypertext – node A to B to C back to B and then to D. The majority of current hypertext systems (e.g. Web Browsers, WinHelp) implement the chronological backtracking mechanism that is shown in column 2. Such functionality is easy to implement using a stack type data structure and adding or popping nodes as the user navigates and backtracks within the hypertext. The disadvantage of such stack-based backtracking is that the same node can

be held several times in the stack (Jones & Cockburn, 1996). Node B in Figure 4.5 has been visited twice by the user and is held twice. The practice of adding 'Back to ...' links on web pages causes most web browsers to add a new reference at the top of the stack. Selecting such page links is different to using the toolbar backtrack button. Recently, new JavaScript back links have been used on the Internet which do actually pop a node off the top of the history stack. However, the use of such links is currently limited by the fact that web designers do not know which path users have taken to the current node. For example, most buttons labelled 'Back' take the user up one level in the web site hierarchy, frequently back to a home page. In some certain situations a user might have reached a node straight from a web search engine, in which case 'Back' will not go to the site home page but back to the search engine. This highlights the current lack of established online linguistic standards.

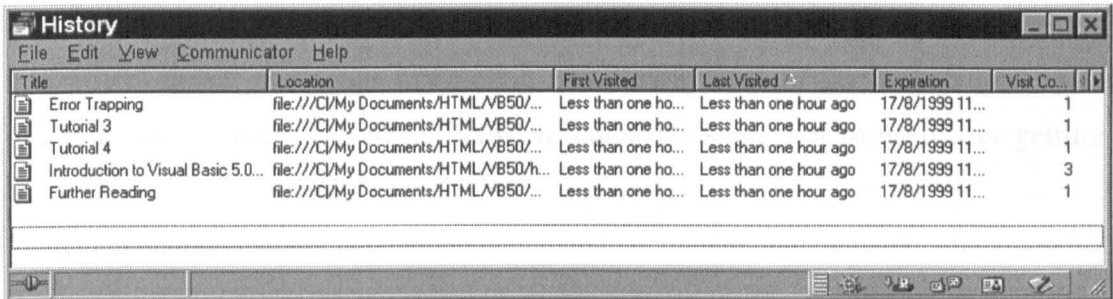
Another problem can arise when a user backtracks a number of steps and then selects a fresh destination node. This new node is pushed onto the top of the history list and consequently losing the ability to forward track (Jones and Cockburn, 1996). Thus, it is important for hypertext systems to implement history lists of all previously visited nodes in addition to the more temporary backtracking mechanisms.

### ***Footprints***

Footprint facilities signal to the user that they have already visited a node previously. Some systems use check marks (e.g. the HyperCard system reported by Nielsen, 1990), while others (e.g. Netscape Navigator and Microsoft Internet Explorer) use link text colour changes. However, there are significant differences in the way Navigator and Internet Explorer implement footprinting. For example, Navigator will only change the colour of a link if the user has traversed that particular *link*, whereas Internet Explorer will change the link colour if the user has previously visited the *node* which the link points to. The difference is clear when browsing WWW sites which use small contents lists at the top of the screen to make intra-page jumps. Netscape will display all contents links as unused, while Internet Explorer will show all links footprinted because they all point to the current node which is actively being visited.

**History Lists**

As already mentioned, history lists are functionally coupled with backtracking mechanisms; each time a ‘back’ or ‘forwards’ button is clicked, the system moves a pointer up or down the history stack one position. History lists are also a specific class of path or trail. Each node visited by the user becomes added to the ‘history trail’ in chronological order. The current History List implementation in Netscape Navigator, shown in Figure 4.6, allows the user to actually reorder the list by node Title, Location, First time and date visited, the Last time the node was visited, etc.



**Figure 4.6** History window provided by Netscape Navigator 4.6.

HyperCard also provides history list functionality with its inbuilt ‘Recent’ command. This displays a clickable set of thumbnail images of each node already visited. However, as Nielsen (1990) points out, each thumbnail is quite small and it can be difficult to discriminate between visually similar nodes, and each node thumbnail is included only once regardless of how many times the user has actually visited the node. In contrast, the History List window shown above in Figure 4.6, provided by Netscape Navigator, lists visited node titles and shows how many times the node has been visited (far right column).

**Overview Diagrams**

Overview diagrams present, typically in two-dimensions, a graphical representation of the hyperspace as a set of nodes (represented using labelled icons) and links symbolised by connecting lines. Such visualisation tools are useful when the hyperspace uses a network-like structure which would be difficult to represent in a simple textual table of contents. However, the limitation, as Nielsen (1990, 1995) acknowledges, is that it is difficult to represent large hyperspaces. A solution used by Nielsen (1990) for his

*Hypertext '87 Trip Report* system was a two level overview diagram. Initially the user is presented with a simplified diagram showing only the main topics covered in the system. After clicking on one of these topics, a new, more detailed, overview diagram appears which 'explodes' the topic in further detail. The *Hypertext '87 Trip Report* contained 95 screens and required a two level overview diagram implementation; it would seem that the current large commercial hypertext with tens of thousands of nodes would make overview diagram use problematic. Nielsen (1990) does suggest that more levels could be added, but acknowledges that too many could indeed create a navigation problem in itself. Balasubramanian (1994) discusses the possibility of using statistical analysis of link traversal in order to generate dynamic overview diagrams. However, this would appear analogous to creating a motorway map of the British road system; fine if the driver wishes to travel between major cities, but not so useful for getting to small villages.

### ***Roam and Zoom techniques***

One of the problems of navigating within hypertext is that the size of the hyperspace often makes it difficult to visualise in the current resolution limited two-dimensional computer interfaces currently in use. To solve this problem Beard and Walker (1987) discuss a 'roam' and 'zoom' interface. A miniature map of the information space is displayed and a wire-frame box represents the proportion currently visible in the rest of the display. The size of the wire-frame box can be controlled allowing the user to zoom in or out of the information space to obtain the required amount of detail. Also, the box can be dragged around the map allowing the user to roam around the information space. Experiments proved that the roam and zoom technique was significantly faster than vertical and horizontal scroll bars.

### ***Table of Contents***

Tables of contents (TOCs) are a standard feature of nearly all non-fiction books. They provide direct non-linear links to the beginning of chapters and sections. In hypertext systems these TOCs can be made active – each reference becomes a clickable link anchor. Because it is possible to quickly refresh the screen display, the TOC in a hypertext system does not have to be a static list as it has does on the printed page.

Instead, expandable/collapsible lists and multipane views are possible (Nielsen, 1995). Chimera, Wolman, Mark and Shneiderman (1994) empirically tested three different TOCs which can be seen in Figure 4.7, scrolling display, expandable/collapsible and multipane. The average time to find a specific section in the scrolling TOC was 63 seconds, 41 seconds for the expandable/collapsible version and 42 seconds for the multipane version. The only task for which the scrolling version proved faster than the dynamic versions was “what is the title of Section 1.1?”.

<p>7. Hypertext on the Internet ▲</p> <p>7.1. Accessing Hypertext</p> <p>7.1.1. Paying for Info</p> <p>7.1.2. Flash Crowds</p> <p>7.2. The World Wide Web</p> <p>7.2.1. Strengths and</p> <p>7.3. HTML</p> <p>7.4. Hyper-G and Harmon</p> <p>7.5. Half-Dead Hypertext</p> <p>8. Coping with Information C</p> <p>8.1. Information Retrieval ▼</p>	<p>▶5. The architecture of Hyp ▲</p> <p>▶6. Hardware Support for</p> <p>▼7. Hypertext on the Internet</p> <p>▼7.1. Accessing Hypertext</p> <p>7.1.1. Paying for Inf</p> <p>7.1.2. Flash Crowds</p> <p>▶7.2. The World Wide We</p> <p>▶7.3. HTML</p> <p>▶7.4. Hyper-G and Harn</p> <p>▶7.5. Half-Dead Hypertext</p> <p>▶8. Coping with Information ▼</p>	<p>6. Hardware Support for Hy ▲</p> <p>7. Hypertext on the Interne</p> <p>8. Coping with Information</p> <p>9. Navigating Large Inform ▼</p> <p>7.1. Accessing Hypertext T ▲</p> <p>7.2. The World Wide Web a</p> <p>7.3. HTML</p> <p>7.4. Hyper-G and Harmony ▼</p> <p>7.1.1. Paying for Informatio ▲</p> <p>7.1.2. Flash Crowds ▼</p>
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A)

B)

C)

**Figure 4.7** Three different designs for tables of contents (From Chimera, Wolman, Mark & Shneiderman, 1994, p. 288). A) Scrolling display, B) expandable/collapsible and C) multi-pane.

Although user searching was faster with the expandable/collapsible TOC than the scrolling display, Zaphiris, Shneiderman and Norman (1999) found expandable indexes were slower than sequential indexes. They used the term ‘index’ throughout their paper, however it appears that they were actually describing a TOC. For example, they describe it as a hierarchy of up to four levels and the terms were not in alphabetical order. In their experiment Zaphiris *et al.* employed two types of TOC, an expandable/collapsible design and a sequential type where the display only showed entries for the current level in the hierarchy. Their findings were unexpected in that the sequential TOC produced significantly faster search times (nearly twice as fast) with hierarchies of 2, 3 and 4 levels deep, and resulted in fewer errors with 4 level hierarchies compared to the expandable TOC. As, the authors acknowledge, they expected performance to be better with the expandable TOC, especially with the deeper hierarchies, because of the additional contextual information available. A tentative explanation for the lower error rate of the expandable TOC than the sequential TOC with a two level hierarchy and then the reverse situation with a four level hierarchy, is



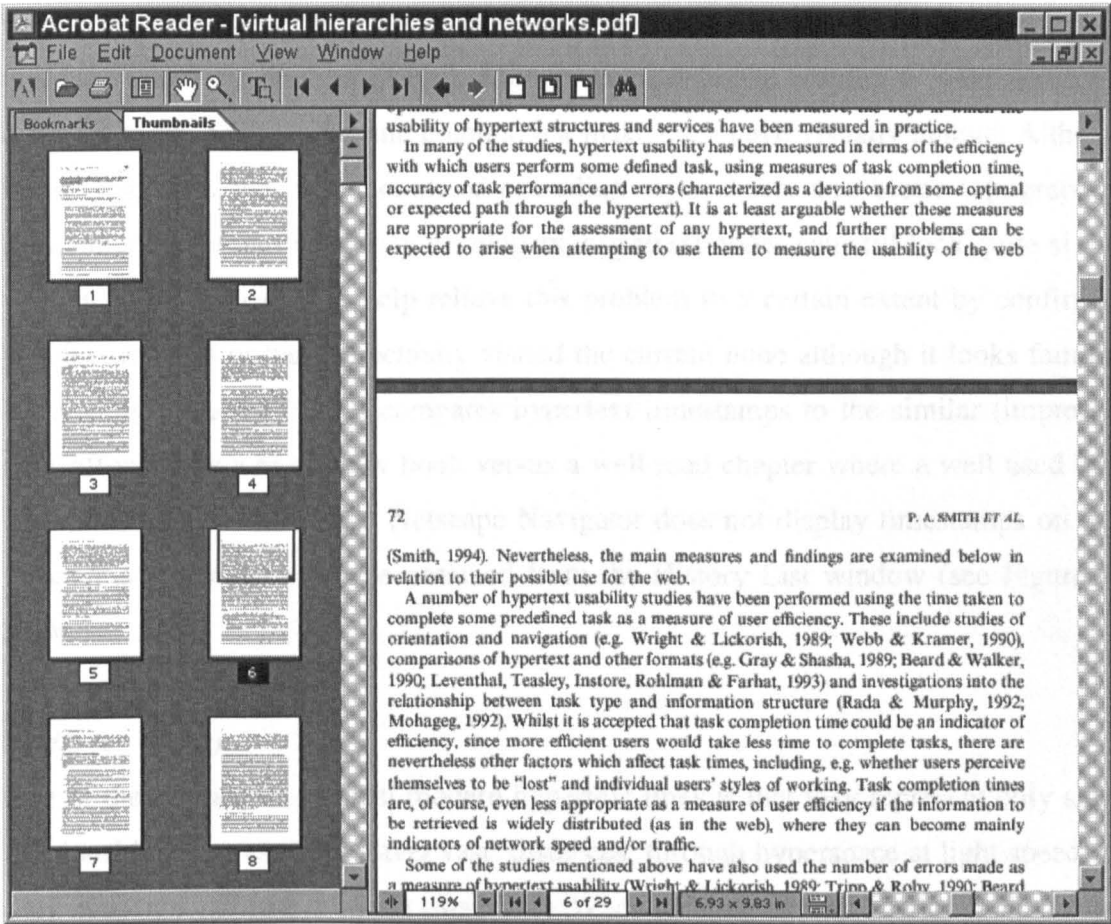
the greater amount of scrolling required in the expandable TOC condition. At lower levels of the hierarchy, when more branches are expanded and thus more items visible, the user has to scroll more (only 20 lines could be displayed at any one time on screen) to identify their current position within the hierarchical structure. However, Zaphiris, Shneiderman and Norman do recommend further research to identify more precisely why users performed worse in general with the expandable TOC. A second limitation of this study was in the use of relatively shallow hierarchies of up to 4 levels. Larger hypertext system will require greater depths but it is unlikely that the results of the Zaphiris *et al.* study could simply be extrapolated for larger hierarchies.

As discussed, most studies of hypertext TOCs investigate their speed of information retrieval or deviation from the optimal number of clicks to get to a particular entry. However, some of the other features present in book TOCs, but which are missing in online implementations, are rarely mentioned. For example, the TOC in a book prints page numbers to allow users to jump to particular sections and chapters, but a hypertext system without its page (node) numbers uses hyperlinks to form the connection. While such links facilitate easy navigation to the required section, they lose the scope information available in print. For example, a book reader can easily calculate the size of a section or chapter by subtracting the start page number of the chapter of interest from the succeeding chapter. Listing the page numbers in hypertext systems employing scrolling nodes would be meaningless. The result would be all sections being one page long. The physical size in bytes or kilobytes would also be meaningless since a node containing graphics or sound could appear to the user as extremely large (assuming textual content). One possibility would be to use some sort of logical description (e.g. number of words or lines) of the section size. However, even such logical descriptions, which are simple for textual information, become problematic when dealing with graphical or audio information formats.

### ***Thumbnails***

Thumbnail functionality has already been mentioned in connection with HyperCard's 'Recent' history list. A thumbnail is a miniature graphical representation of a node, either all the nodes in a system, or as is the case in HyperCard, only those nodes in the

History List. The advantage of thumbnail functions is that they allow the user to gain a broad overview of, if not the whole system, then a number of nodes at once. However, the problem, as already noted, is that most thumbnail views are small and are difficult to identify accurately when many nodes are visually similar. As the screenshot of Acrobat 4.0 in Figure 4.8 shows, the mainly textual nodes look very similar. Another limitation of thumbnails is that they are primarily visual. Although it might be possible to play the audio content of a node, if many nodes include audio the result would be a cacophony of noise.



**Figure 4.8** Thumbnail navigation provided by Adobe Acrobat Reader 4.0.

The thumbnails in Figure 4.8 also highlight the problem of node size already mentioned earlier in Section 4.3.4. Adobe Acrobat, because it is designed to support the cross-platform delivery of paper-documents, typically uses A4 (or US equivalent) paper sizes.

However, these portrait documents are then rendered onto a much lower resolution landscape oriented visual display unit. Thus, as can be seen in thumbnail number 6, the red rectangle represents the *presentation* size while the thumbnail itself represents the *logical* page size of the node.

### ***Timestamps***

Timestamps, like footprints, provide cues to the user about which nodes have been visited previously. The time elapsed since the node was last visited could be displayed, as in Nielsen's (1990) *Hypertext '87 Trip Report*, or the total time spent viewing the node could be presented. Timestamps are useful for combating the *homogeneity* problem raised by Nielsen (1990). Modern printed books employ a wide variety of different fonts, sizes, styles and colours that make each page visually unique. Although improving, with the introduction of cascading style sheets and better typographical awareness on the part of system developers, hypertext nodes can still look quite similar to each other. Timestamps help relieve this problem to a certain extent by confirming that the user has or has not actually visited the current node although it looks familiar. By analogy, Nielsen (1990) compares hypertext timestamps to the similar (imprecise) cues afforded by a brand new book versus a well read chapter where a well used book always falls open. Although, Netscape Navigator does not display timestamps on each node, this information can be obtained from the History List window (see Figure 4.8 above).

### ***Trails (or Paths)***

One of the limitations of most modern hypertext links is that they represent only single relationships. The user can travel vast 'distances' through hyperspace at light speed, but only in a 'straight' line between two points. When arriving at a destination node the user must examine the current star system to orientate themselves before hyperjumping to another location. This form of navigation appears to be like a learner driver 'kangaroo hopping' in a powerful sports car. To be able to change hypertext into second gear, chains of links have to be created. This was one of the main ideas in Bush's (1945) Memex proposal. Two items could be linked together, just as current hypertext supports, but importantly this link is then added to a trail of many related links.

“...when numerous items have been thus joined together to form a trail, they can be reviewed in turn, rapidly or slowly, by deflecting a lever like that used for turning the pages of a book.” (Bush, 1945, p. 107).

#### **4.3.7 Querying**

Based on his observations of users interacting with the NoteCards system, Halasz (1988) argued that navigational access alone was insufficient. Often the users could describe exactly what information they required but simply could not find it in the network. Although, Halasz acknowledges that various additional navigational support tools could be added to NoteCards, for example fish-eye views and graphical flyovers, he recommended the addition of query-based access mechanisms as the most efficient way of solving users' information retrieval problems.

##### ***Indexes***

Traditional book-type indexes can easily be created in hypertext. Some systems, such as MS WinHelp, specifically support indexes. However, any hypertext can support an index, in theory, by creating a set of links from a number of keywords to their relevant nodes. Although an index can be time-consuming to author, its advantage is in greater precision and lower recall, in terms of the quantity of nodes matching, compared with full-text search routines.

##### ***Searching***

Although less precise than an index, search routines have the advantage of automation and so are thus inexpensive. Halasz (1988) makes a distinction between two primary forms of searching: content-based searches and structure-based searches. The first type, typically found in most information retrieval systems, works by accepting a search term or terms (plus boolean operators) and then returning matching nodes, no use is made of the structure in which the hit nodes are found. Hypertext systems such as WinHelp, Adobe Acrobat and DynaText implement content-based searching by allowing the user to enter various keywords into a search routine. The second type of search, described by

Halasz (1988) is the structure search. Such a search allows the user to retrieve a group of nodes based on their associated link structure. For example, to find two nodes connected by a 'supports' type link. Potentially, a system implementing both content and structure searches together with typed links would be very powerful. For example, such a system would be useful for dispensing chemists. For patients taking two or more different medicines at the same time, the chemist could run a query to return the nodes describing the medicines only if they are not linked with a 'dangerous interaction' link type. In effect the chemist is utilising information distributed across nodes *and* links, instead of just node content as is typically the case in most hypertext implementations.

Searching textual information sources is a relatively simple process using a combination of keywords and boolean algebra. However, text is only one data format out of many in modern hypertext systems. Searching for graphics, sounds or video clips is a much more difficult problem. Two solutions initially present themselves. Firstly, a set of textual 'tags' could be added to a piece of data to identify the format of the information (i.e. image, video, sound) and then some keyword tags to summarise the actual content (e.g. motor racing video, Beethoven's 9th Symphony). However, such meta-tags appear to be crude and offer only limited search capabilities. A system designed to allow the user to actually search the content of the required information is described by Hirata, Mukherjea, Okamura, Li and Hara (1997). To search for an image, for example, the user draws a simple representation and then the computer, using area and overlap analysis techniques, identifies images which are similar. Although, it is possible for the user to draw a circle on top of two vertical lines and find an image containing a tree, there are limitations to the system. For example, a user might draw a 'smilie' to find the Mona Lisa, however the possibility of low precision becomes a problem if the system contains thousands of portraits, or the user is not very artistic. Although Hirata *et al.* (1997) do not cover audio searching, this too raises some interesting problems. For example, is it necessary for the user to sing or hum part of a piece of music in order to search for it? It is likely that the effective searching of non-textual data might require a combination of different search techniques. Thus, if an outline of a face finds 9,950 different portraits, then the user (if not artistically inclined) could enter textual parameters to narrow the search to selected artists or years when the painting was thought to have been created.

Another search might involve starting with a textual search firstly, to return all the songs created by a particular rock group, and then humming a short example to further refine the search.

#### **4.3.8 Collecting**

The navigating and querying control structures considered thus far primarily concern data-access tools. However, as Norman (1994, p. 46) writes: “Particularly in education tools are needed not only to find information but also in the analysis, generation, and presentation of information.” The next three control structures, collectors, manipulators and planners, are designed to perform such tasks. Written English often uses repetition and superfluous words to aid understanding, however the main concepts of a chapter are often found in a few keywords or sentences. Collection tools allow users to ‘draw out’ these key concepts as an aid to further manipulation. Two distinct types of collection tool are presented by Norman and Wright (1993):

1. **Pickers** – extract items from the primary hypertext and present them for use in alternative systems. Examples include clipboards and notebooks.
2. **Pointers** – point to various items still stored within the primary hypertext. An example implemented in many current hypertext systems is bookmarking. However, it could also be argued that highlighting tools also act as visual pointers to various parts of a hypertext.

The collection of salient information is often conducted before the information is manipulated in the process of restructuring or synthesising new information.

### 4.3.9 Manipulating

Gall and Hannafin (1994) use the term 'connecting' in their hypertext framework. However, allowing the user to add their own links between nodes is only one control action out of a number which could be termed 'manipulation'. As Norman and Wright (1993) observe, many of the tasks involved in serious reading require analysis, synthesis, restructuring, or evaluation of the information collected. Gall and Hannafin suggest that 'collecting' occurs when the user is able to select various pieces of information from a hypertext and then assemble them in a new form away from the original system. However, this would appear to be a somewhat artificial distinction which excludes some important manipulation tools such as annotation which are applied to the primary text/hypertext under investigation. More sophisticated manipulation tools discussed by Norman and Wright include facilities to sort and classify information by user-defined criteria. Without these tools Norman and Wright argue that some data sets could be too large to effectively remember or process. Current hypertext systems assume that this form of manipulation will occur elsewhere.

### 4.3.10 Planning

As discussed at the beginning of Section 4.3, Gall and Hannafin (1994) list four basic hypertext control structures in their framework: searching, browsing, connecting and collecting. However, an important fifth control structure is missing, that of planning. As Norman and Wright (1993) argue, serious reading tasks require some kind of plan concerning how to accomplish the task. The task itself must be understood, the resources (e.g. tools) available known, and alternative methods of attack evaluated before a plan is executed. Paper-based textbooks sometimes provide sections about how to use the book effectively. However, because hypertext is computer-based, more sophisticated intelligent agent planners are possible. By monitoring a user's behaviour and observing inefficient interaction, for example the repeated use of a particular command, a planning agent might intervene with an alternative suggestion. However, the 'intelligence' of such an agent would need to be sufficiently high to be trusted and

relied upon by the user to provide useful advice. The *Office Assistant* in Microsoft's Office 97 can provide tips to improve productivity, but many users seem to become irritated with trivial non-productive suggestions and quickly deactivate the agent.



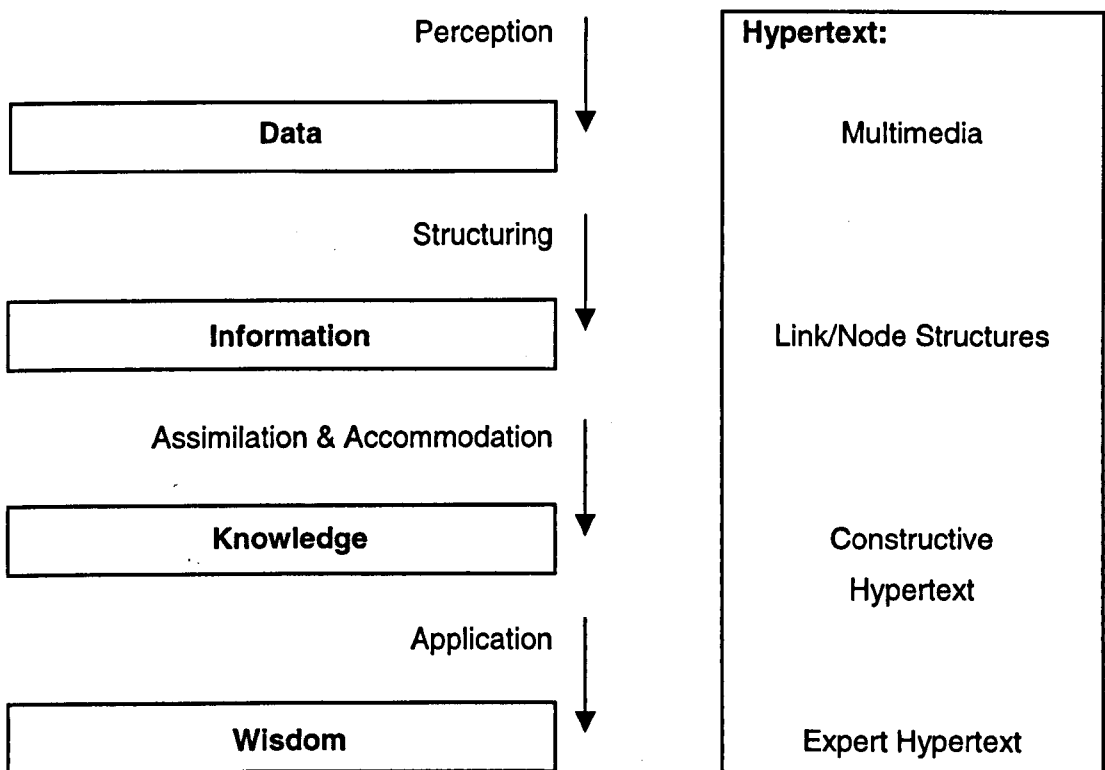
## 4.4 Applications of hypertext

Having explored in some detail the ‘anatomy’ of modern hypertext, the current section turns to investigate the main uses to which hypertext has been put before, in Section 4.6, examining empirical studies of hypertext for learning relevant to the current thesis.

A large number of researchers in the field often quote Bush’s (1945) seminal paper on a possible information retrieval solution. Although Bush (1945) did not set out to create a new educational medium, current hypertext systems have been applied to every stage of human cognition. For example, Winn (1997) lists four distinct terms which can be used to categorise cognition: data, information, knowledge and wisdom. Data is the small proportion of energy which individuals can perceive through their senses. Data is processed and structure is imposed, much of it pre-attentively (Arbib & Hanson, 1987; Marr, 1982), to become information. Information is then attentively processed to build knowledge about how the world operates. But, as Winn (1997, p.38) states, “Knowledge should be a means to an end not an end in itself.” Wisdom is the judicious application of knowledge.

Winn’s (1997) four stages of cognition are elaborated in, Figure 4.9 by adding various types of hypertext to each level. Initially, at the beginning of the process, hypertext can be used to present two main forms of energy: light and sound. Multimedia formats such as text, graphics, animation, video and audio are common to many modern hypertexts. However, there is no real reason why hypertext should be limited to the senses of hearing and sight. With appropriate force-feedback hardware it is possible to imagine users being able to ‘touch’ virtual objects. Whichever data format is employed all hypertext systems employ certain structuring to this energy. For example, textual material can be structured into a linear narrative, hierarchical structure, or associative networks. Whereas hypertext has broken the traditional sequential nature of text, audio and video information is more sequential. Although it is interesting to see that in an episode of the science-fiction series *Babylon 5*, a hypertext television was demonstrated. Moving to the next stage in the cognitive life-cycle it is interesting to notice the crossing of a conceptual watershed. On one side the cognition is easily shared

and available for inspection and the hypertext systems are mainly *presentational*. However, on the knowledge and wisdom side of this imaginary watershed, cognition becomes more unique and private to an individual. The cognition changes from a publicly presentable form into a private *representation*. Individuals form knowledge when they attentively process information and integrate it into their existing understanding of the world. Because every individual's prior knowledge is different, the conversion into knowledge is a personal experience and phenomenon. At the heart of the constructivism theory of learning is the tenant that it is the learner who 'constructs' their own internal representation of reality. In this context, constructive hypertext in which an individual can use a hypermedia system to externalise their own unique understanding of a concept appears ideal as it can circumvent the limitations, discussed earlier in Section 2.4, Cunningham, Duffy and Knuth (1993) cite for books.



**Figure 4.9** The transformation sequence of data, information, knowledge and wisdom, and the types of hypertext which support these different kinds of cognition.

#### 4.4.1 Information retrieval

It could be argued that most hypertext systems, with the possible exception of authoring tool systems, facilitate information retrieval. While this is true there are some systems where the whole emphasis is on the quick and easy location of required information.

##### *Walk-up-and-use Systems*

A hypertext system displaying illuminated medieval manuscripts was created for the Getty Museum (Nielsen, 1995). This allows visitors to page through and gain an impression of these fragile documents without damaging the originals. The traditional solution to this type of problem has in the past been to display one or two single sheets from the manuscript behind protective glass cases. However, as Nielsen remarks, this removes the pages from their natural context as part of the whole book. The hypertext, because it allows user to access all digitised pages, does not lose this important context.

##### *Reference Works*

Hypermedia encyclopaedias are probably the most successful application of hypertext to date, with more copies being sold than print editions (Nielsen, 1995). Their success is derived from their use of multimedia information formats which are not possible with paper. For example, the *American Sign Language Dictionary* contains 2,181 video clips illustrating various signs. Printed dictionaries display static pictorial diagrams with arrows indicating movement. Some hypertext dictionaries (Microsoft Bookshelf, Concise Oxford English Dictionary) also have the ability to reproduce sound recordings of how various words should be pronounced. In each case it would appear as if these hypertext reference works are more popular than their paper counterparts because they are more cognitively efficient (see Section 4.2.2).

#### **4.4.2 A writer's tool**

Most hypertext systems create associatively linked nodes of information to be read online using a computer. However, Smith, Weiss and Ferguson (1987) created a hypertext system to support authors in the task of writing. The researchers studied the process of textual comprehension – read linear exposition, form hierarchy of relationships and then a network schema of associated concepts – and used it as the basis of a hypertextual writing tool. Viewing the writing process as the opposite of the reading process, their system allows the creation of associated ideas initially with no clear structure. Following this a number of commands can be used to construct a hierarchy and then from this structure a linear representation of the text can be printed.

#### **4.4.3 Communication medium**

Hypertext can be viewed as a communication medium from two different perspectives: 1) a medium capable of supporting communication and interaction between two or more individuals, and 2) the use of hypertext and associated networking technologies to disseminate information. ARPAnet, the forerunner of the Internet, was developed at CERN to facilitate the collaborative sharing of ideas in a computer augmented environment. A few decades later and the Internet facilitates a wide variety of communication facilities: email, newsgroups, chat rooms, MUDs and shaded workspaces. Although some of these technologies are not hypertext systems in the strictest sense, arguing about the precise semantics is not productive in contemporary situations involving multiple systems and sub-systems to create holistic working and learning environments.

#### **4.4.4 Document management**

The Networked Learning Environment (NLE) being constructed as part of the TLTP3-86 project at the University of Newcastle, University of Durham and the University of

Nottingham incorporates various document management facilities into its hypertext functionality (NLE, 2000).

### ***Curriculum Management***

One of the problems of a five year medical course taught by hundreds of lecturing and clinical staff across many different departments is that it is often difficult for teaching staff to know when and where a particular concept is covered. For example, the issue of 'patient consent' is an important concept which is vital for all new doctors. However, discovering in which year and semester this is taught and by whom is currently very difficult (Dennick, 1999, personal communication). The NLE uses database storage to create an easily updateable virtual learning environment with a web-based hypertext user interface. Functionality within this user interface allows both staff and students to navigate within the conceptual structure of the medical degree and to run direct queries on the underlying datasets for specific topics or resources. Within the first year of the project a number of minor curriculum problems were discovered and subsequently resolved. Such minor issues, as will be discussed further in Section 6.3.5, can easily be overlooked when formatting information for paper-based media. On several occasions meetings had to be arranged to decide exactly where in the curriculum a certain topic should go and where a link should be included. However, the inclusion of a visible hypertext link has crystallised many informal and somewhat imprecise conceptual relationships into very explicit relationships. This has been seen on the NLE project as a very positive side-effect of the use of hypertext technologies to support the curriculum.

### ***Version Control***

Version control normally refers to the ability of a system to manage and present multiple distinct versions of a document or set of documents. Although the NLE will not store previous states of its knowledge base, it will facilitate more efficient control of the 'current' version. For example, the system stores most of the data in a central XML database; using style sheets, records are retrieved and formatted for multiple purposes: screen, student handout, quality assurance report. The main advantage of this approach is in lower maintenance: instead of updating three or more separate versions on multiple media, the author(s) only need to update a central repository.

#### **4.4.5 Pervasive hypertext**

Increasingly there is a sense that a fifth hypertext genre might exist in which the technology of hypertext becomes transparent and ubiquitous. For example, although it is now possible to construct hypertext links in Microsoft Office 97 documents, users do not categorise these applications as hypertext, they are simply writing a letter, technical report, preparing a presentation or query a database. The same can be argued in the use of the Concise Oxford English Dictionary with its hypertext functionality – users are not consciously using a hypertext system they are simply looking up a dictionary definition. Indeed, the precise definition of what constitutes a web browser and an operating system are being debated in the current Department of Justice (DoJ) hearings involving Microsoft. Looking at Windows 98, although the Internet Explorer web browser is tightly integrated there are other features which could be considered hypertext-like. For example, the use of shortcuts to point to objects is similar to links, and the addition of backtracking and forwardtracking functionality into desktop windows (even for local drives) is a direct use of hypertext-derived technology. As greater numbers of applications and devices (e.g. TV to WebTV) assume various levels of hypertext functionality it might not be possible in the future to talk about hypertext as a separate field in its own right.

#### **4.4.6 Education**

The reason why the educational uses of hypertext are listed last is because, under closer inspection, the field of education actually uses many of the aforementioned applications of hypertext. For example, information retrieval is an important issue for students trying to locate a specific piece of information within a large hypertext system. Communication, as will be discussed below, is essential in learning not only for distance education programmes but also for communication with peers and tutors. Just as with libraries which spend time managing their collections, so too is document management systems important in educational hypertext systems. Within a large

curriculum it is important that teaching staff cannot accidentally overwrite the material of colleagues.

There have been a number of educational hypertext studies conducted. Marchionini and Crane (1994) describe the Perseus Project which contained Greek texts with corresponding English translations together with approximately 30,000 images. The researchers report using the system in three modes of teaching (lecture, self-directed learning and small group discussions) with 640 students at 6 higher education institutions. Other systems developed included *Intermedia* at Brown University (Yankelovich, Smith, Garrett & Meyrowitz, 1998) which concentrated on linking protocols; *Microcosm* (Lowe & Hall, 1999) which separated links from the content to improve the management of large hypertexts; *Hyperties* (Shneiderman, 1987) which used embedded menus to facilitate browsing and the commercial systems *Guide* (Brown, 1987) and *HyperCard* (Apple, 1987).

Even though some of the systems mentioned above are now quite old, several have continued to be developed further. However, as Nielsen (1995) comments, Bill Atkinson who developed HyperCard admitted to not designing a hypertext system from the beginning. Many of the systems were originally developed primarily to solve various electronic document management problems: linking, information retrieval, browsing, etc. Many research projects have utilised these various systems within *traditional* educational practices such as adjuncts to lectures or tutorials. However, as Pang (1998) argues:

"It [hypertext] also threatens conventional pedagogy. Traditional teaching, like writing, is linear and top-down. Lectures are exercises in the delivery of canonical bodies of knowledge, while seminars are intellectual plays directed by academic authorities, and both are directed by god-like (or author-like) professors. Hypertext does not lend itself to such teaching methods. It requires a more egalitarian and sophisticated pedagogy, in which the distinction between professors and students, indeed between 'central' and 'peripheral' works, is rendered irrelevant."

So, taking Pang's argument, what role can hypertext play in supporting learning? To understand this it is necessary to step back from hypertext and consider educational courseware in general. Courseware, as with any type of software, is usually written with the goal of supporting a particular task or set of tasks. The problem with this task-oriented approach when applied to the field of education is that:

"Learning cannot be approached as a conventional task, as though it were just another kind of work, with a number of problems to be solved and various outputs to be produced. This is because learning is a by-product of doing something else. It is the 'something-else' that needs support."

(Mayes and Fowler, 1999, p. 485)

Mayes and Fowler (1999) refine this 'something-else' into three discrete stages in a learning cycle:

- **Conceptualisation**

The process through which an individual with their pre-existing framework of understanding experiences new concepts.

- **Construction**

The process of building and accommodating concepts through the use of meaningful tasks, typically laboratory work, writing, giving presentations, etc.

- **Application (or Dialogue)**

An individual tests their new understandings by a process of dialogue, especially with teachers/lecturers and peers. Where differences between individuals occur a process of tuning occurs by one or both parties returning to the conceptualisation stage again and repeating the process.

Using these three stages of learning, Mayes and Fowler (1999) identify three types of educational courseware – primary, secondary and tertiary, that support the conceptualisation, construction and application phases respectively.



Using the learning cycle as a theoretical framework, it becomes obvious that an IT-based integrated learning environment requires all three types of courseware. Most educational systems, as Mayes and Fowler acknowledge, are primary courseware in type. Examples such as SuperBook (Landauer *et al.*, 1993) and Perseus (Marchionini & Crane, 1994) provide rapid hypertext access to large corpuses of information. One of the advantages frequently offered for hypertext as primary courseware is its ability to offer an exploratory discovery environment for individual learners. However, what is interesting is that as well as its use for individual study, the Perseus system was employed to support lectures. In this capacity a computer containing the Perseus system was linked to a data projector so that its image could be displayed on a large screen visible to the whole lecture theatre. The lecture can then be conducted not from a static PowerPoint presentation, but from a dynamic navigation and discussion through part of the Perseus repository of multimedia information.

Following the acquisition of new concepts, learners require tools to help them construct their understanding. While this understanding is cognitive and thus an 'internal' process, several aspects can be aided by external tools. The emphasis of such secondary courseware shifts from the support of the original author's ideas, as is the case with primary courseware, to support for the learner's ideas. Although such systems cannot 'directly' influence a learner's cognitive schema, they can play important roles in supporting 'external' activities. For example, Mayes and Fowler (1999) posit that exploratory applications such as LOGO can support and foster knowledge construction. They also include creative systems such as Authorware and Director and even go as far as to include standard office applications as secondary courseware when used to help individuals to organise their understanding of a concept.

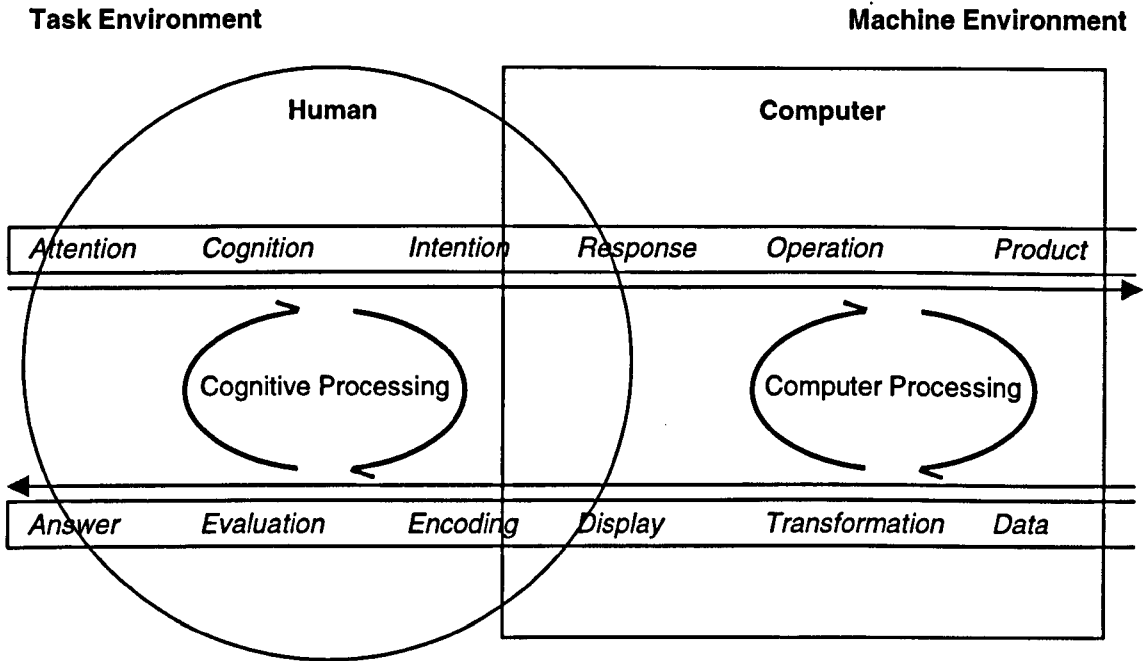
Having formed a mental model of a particular domain, a learner needs to engage in a dialogue with others, peers or lecturers, in order to determine if their newly constructed mental model is consistent with socially accepted norms. This is a new area of educational systems. Devices such as email and newsgroups provide asynchronous communication, whereas more sophisticated digital whiteboards, desktop video conferencing and chat can support synchronous communication. However, Mayes and

Fowler (1999) suggest that a key area of tertiary courseware will be the application of vicarious learning. This entails the reuse of prior learning situations for the benefit of subsequent students. For example, a frequently asked questions (FAQ) list based on actual student questions gathered from one semester or year could be packaged, together with associated answers, for the use of students the following session.

A new generation of hypertext systems designed specifically for education are now beginning to be developed. Commercial systems such as WebCT and BlackBoard show the growing maturity of such educational markets. Many of these products now contain varying support for all three of Mayes and Fowler's (1999) courseware types. However, further research is still needed to determine which features are necessary to support any knowledge domain. For example, it is interesting that 15 out of 21 UK medical schools have decided not to adopt any commercial hypertext systems (Cook, 2001). Instead they have either developed their own in-house or as part of TLTP or FDTL funded consortia. Even within the same field, there are differences in the approach adopted by different medical schools. For example, at the University of Nottingham all resources are uploaded, including lecture notes and handouts, so that the system can be used by staff, as well as students, as a kind of curriculum auditing tool. Whereas, at Cambridge University (Whittlestone, *personal communication*), lecture handouts are not provided online because of the costs associated with printing, maintenance of printers, and the problems associated with reading large amounts of text from the screen. These differences have probably evolved out of the different institutional cultures/policies at each institution; the question remains is what is the practical effect of such differences on student learning.

## 4.5 Hypertext in practice

Following on from the review of hypertext structures and hypertext applications presented above, this section considers some of the main empirical results of studies of hypertext use. In view of the potentially very large number of factors implicated in studying hypertext use, a simplified model of HCI (Rada, 1995) has been used to organise this review. Although there is general agreement that aspects of both the human and computer sides of the interaction equation should be investigated, a whole plethora of ideas regarding what other variables exist. Such important variables as task, ergonomics, social and organisational aspects all play key roles in determining the ultimate usability of a system. To accommodate these disparate aspects of the interaction, Rada (1995) proposes a Human-Computer Interaction model that includes an environmental aspect. As Figure 4.10 shows, the human and computer entities operate within a broader task and machine environment. Using this conceptual framework the next four sections will review the empirical hypertext literature from: computer, human, task environment and machine environment perspectives. It should be noted that these perspectives are covered separately for convenience, in reality all four operate simultaneously in any form of human-computer interaction.



**Figure 4.10** General model of Human-Computer Interface. The human is represented by a circle and the computer by a rectangle. Both circle and rectangle include the processes performed by the human and computer. The overlapping area indicates processes related to the interface. Arrows indicate information flow. (from Rada, 1995, p. 13).

### 4.5.1 Computer

Landauer, Egan, Remde, Lesk, Lochbaum and Ketchum (1993) discuss the evolution of the SuperBook system over three versions. By analysing the log files of subjects operating Version 0 it was found that system response speed was a significant factor in the search time superiority of the paper book used for comparison. The logs also revealed that users tended to perform searches instead of browsing the table of contents. As a result of rewriting the code in a faster language and by changing the functionality of the user interface it was found that the performance of SuperBook Version 1 was similar to that of the book. Reviewing the log files for Version 1 showed that users often searched for a word and then looked it up in the table of contents, a process which took on average 10.8 seconds. By automating the process so that SuperBook automatically selected the table of contents after a search, the performance of the users on Version 2

was 25% faster and 25% more accurate than the paper book copy. Although only the functionality of the user interface was addressed, large performance increases were found for SuperBook in supporting the same subject matter content and the same tasks.

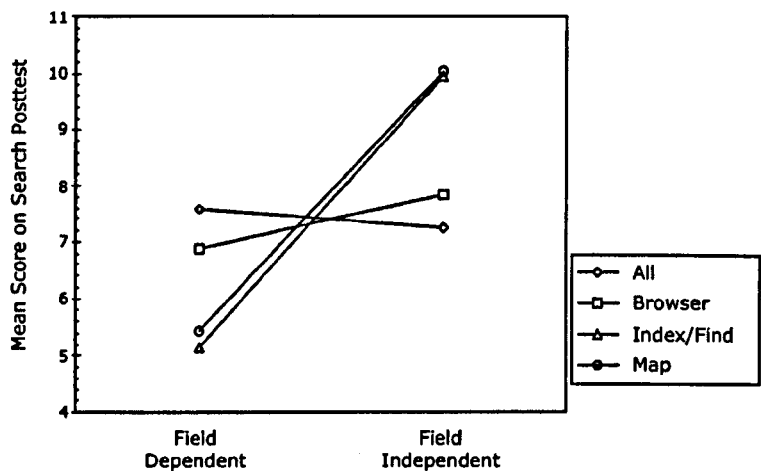
#### **4.5.2 Human: Importance of Individual Differences**

Nielsen (1989) argues that designers cannot attend to all the factors which influence hypertext. Thus, he states that it is important to work out which aspects of a hypertext design will have the largest effects on usability. In a literature review, he reports that the top three studies with the largest usability effects all involved individual differences, rather than interface or task differences. In another meta-analysis, Chen and Rada (1996) found that cognitive styles had a small effect on effectiveness, measured in terms of achievement, and efficiency, measured in terms of time required to complete the tasks. However, they discuss several studies which found spatial ability did influence hypertext interaction more directly. Höök, Sjölander and Dählback (1996) report similar findings – subjects with higher spatial ability completed the tasks faster than low spatial subjects (although using a similar number of mouse-clicks). Chen and Rada (1996) report that some studies found that performance differences resulting from spatial ability could be narrowed somewhat by the use of graphical maps of the hypertext structure.

##### ***Cognitive Style***

As mentioned in Section 3.4, over 30 different cognitive styles can be found in the literature. One of the more widely used constructs is that of field dependence. As far back as 1979 Goodenough reports that nearly 2,000 bibliographic articles can be found on the subject. Leader and Klein (1996) investigated the relationship between field dependence and four different hypermedia conditions: browser, index/find, map and all three facilities combined. As Figure 4.11 shows a significant interaction between search tool and cognitive style occurred. The performance difference between field dependent and field independent groups using all the Index/Find and the Map were statistically significant. However, the performance of the two groups was not significantly different

using the Browser or when given all the search facilities. Leader and Klein (1996) report that contrary to expectation, field-dependent subjects performed poorly in the map treatment. However, they go on to explain that the way the map was implemented (i.e. on a secondary screen) might have interacted with cognitive style.



**Figure 4.11** Effects of search tool and cognitive style on search test achievement (from Leader & Klein, 1996, p. 11).

More recently Ford and Chen (2001), using the CSA test of cognitive style, found significant differences in the increase in students conceptual knowledge between pre and post-tests when assigned to experimental conditions matching their styles. The matching conditions consisted of: 1) a hypertext system structured on a depth-first concept explanation principle for field-independent subjects, and 2) a hypertext system covering the same material using a breadth-first structure for field-dependent subjects. What is interesting about this study is that Ford and Chen (2001) found a significant interaction between gender and experimental conditions. They found that males outperformed females in the *matched* conditions, but did not show any significant differences in the *unmatched* conditions.

**Personality**

The personality factor Locus of Control (LOC) was studied in relation to hypertext by Gray, Barber and Shasha (1991). They found that subjects classified as having an Internal LOC were faster than those with an external LOC with both dynamic text (a

special type of hypertext) and paper text. The author also reports a significant correlation between general academic ability (as measured by the mean grades of students) and the number of correct answers. In addition, analysis of the keystroke software logs revealed the tendency for subjects with higher grades to permit themselves to 'get lost' more often. That is, these students navigated more confidently accessing a greater number of different screens in less time than the students with lower grades.

### ***Level of Knowledge***

Lawless and Brown (1997) cite various studies of educational multimedia learning environments. They found that although various studies reported that learner control can increase retention and improve attitudes, subjects with low domain knowledge find navigation harder and can miss complete sections of the learning environment, leading to incomplete domain models being acquired. Korthauer and Koubek (1994) studied the relationship between level of domain knowledge and subjects' field-dependence cognitive style. Interestingly they found that although field-dependent subjects usually prefer external frames of reference, they still did not perform as well as the field-independent subjects. Korthauer and Koubek (1994) speculate that the field-dependent subjects performed less well than the field-independent subjects, even though the material was structured, because there was a mismatch between this external structure and the internal (or cognitive) structure of the subjects. The field-independent subjects performed better because they were able to reconcile this difference by adapting their own mental models or restructuring the experimental material.

### ***Motivation***

The ability of technology to enhance motivation, and thus performance, was investigated by Gilliver, Randall and Pok (1998). They conducted an experiment using 444 first year students, 111 of which were assigned to an experimental group and the remaining 333 assigned to a control group. The experimental group, as well as normal class activities, were also permitted to utilise an 800 page Internet web site to support their course. The web site was designed to offer three 'streams' of learning for slow, average and advanced learners. The students had complete freedom to choose between

the three streams, but they were subtly guided within a stream until they indicated they were ready to move by selecting different material. Subjects using the experimental web site achieved a mean mark of 71.4% in a written examination, compared with a mean mark of 64.5% for the control group. This difference was statistically significant ( $p < 0.001$ ). Interestingly, Gilliver *et al.*, (1998) attribute the better performance of the experimental group to the streaming employed in the web site. They report that advanced students assigned to the experimental group performed 14% better than advanced students assigned to the control group and struggling students performed 12% better in the experimental group, but average students only improved by 2% when assigned to the experimental group. The authors suggest:

“...that the stronger and weaker students are finding course material on the Internet more appropriate for their respective levels of understanding, and are therefore more interested and motivated to understand and absorb the content. Average students are not finding the same opportunities – a challenge for future site revisions to address.”

*Gilliver et al., (1998) p. 220.*

It would appear that this study should be interpreted with caution. For example, was the improvement of subjects assigned to the Internet attributable to the change in medium (i.e. using the Internet), the addition of an *extra* medium to their normal studies, or because their motivation was increased by the instruction being more suitable to their ability? The question remains, “would similar performance improvements occur if streaming was implemented using alternative forms of education such as lectures, tutorials or books?”

### **Conclusions**

Caution should be exercised in reviewing research concerning online learning environments. For example, Mayes and Fowler (1999) distinguish between two different forms of usability. They argue that learners should be able to effortlessly navigate to the conceptual level but then be critically engaged by its meaning. Using this distinction it becomes clear that two distinct usability problems could occur in the use of hypertext systems. The first is that the functional design of the system could



cause problems for certain individuals by, for example, overloading low spatial users with complex link structures. A second problem could then occur at the conceptual level, whereby an individual with a predominantly verbal style of processing information, encounters difficulties understanding material represented pictorially. Although both problems are likely to affect the amount of material learnt, the first issue is interesting because it might be inherent in the design of the system. By careful design of a hypertext system to ensure that both high and low spatial ability users can operate it, for example, all a lecturer would need to worry about was the content of the system.

#### 4.5.3 Task Environment

In a meta-analysis of hypertext literature, Chen and Rada (1996) found that in 8 studies hypertext was more *effective* than non-hypertext and 5 the opposite. Although the studies utilised different measures, effectiveness was generally calculated using number of questions answered correctly, accuracy, total number of commands used, or learning outcome. Chen and Rada (1996) also reviewed studies investigating *efficiency* and found one study that concluded hypertext was more efficient than non-hypertext methods and four studies supporting the opposite. Efficiency was variously measured using completion time or the number of tasks completed in a set period. However, a more detailed review of individual projects reveals that the important factor was not the hypertext system or book as a whole, but in fact the task being attempted. For example, Lehto, Zhu and Carpenter (1995) found that when they compared a 529-page book with a hypertext equivalent, they found the book supported learning tasks better than hypertext (summarising, concluding and making suggestions), while hypertext was over four times faster than book when subjects were required to retrieve specific facts. Likewise, Leventhal *et al.* (1993) also found that hypertext was most advantageous for answering questions relating to specific facts found in the body of the text (using searching). The authors did note that although the hypertext users were better at answering this factual look-up question than book users, this type resulted in the lowest accuracy rate of all the question types. They conclude that although the hypertext had full-text search capabilities, its use was not intuitive. Questions which revealed an

accuracy advantage for the book were the question types: a) non-text facts (i.e. information had to be retrieved from a map for example), and b) inferential/non-text questions which required information from both a text node and a graphical node. Riding and Chambers (1992) also found that for questions requiring multiple nodes ('Comparative' type), book was more effective than hypertext. 'Factual'<sup>8</sup> and 'Interpretive'<sup>9</sup> question types were more effectively answered using hypertext, and 'Deductive'<sup>10</sup> slightly better using book. Finally, the results from three SuperBook versions found that through iterative design and evaluation, a hypertext system which was slower and less accurate than a book could be made about 11 per cent more accurate than the book and nearly two minutes faster than the book (Landauer *et al.*, 1993).

Surrounding these specific task types lie more general tasks such as self-directed learning, exploratory learning and group projects. Although some may argue that these are in fact learning/teaching styles, the students must complete various tasks within each overall style. Ellis (1997) argues that interest in educational technology is raising many fundamental questions in the minds of higher education lecturers:

"The recent focus on using educational technology in instruction has led to a general renewed interest in *how* we are teaching, both with technology and without. As part of moving to the online environment, many instructors have come to appreciate the need to re-think the teaching and learning approaches they have traditionally used."

(Ellis, 1997, p. 259)

So even if the technologies do not live up to all the hype, viewed as a catalyst prompting critical self-evaluation, they can be seen as successful initiatives.

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<sup>8</sup> e.g. "What is meant by the term 'ecosystem?' Give three specific examples to illustrate your definition."

<sup>9</sup> e.g. "In what ways can fields be destroyed by irrigation."

<sup>10</sup> e.g. "Describe some of the possible causes of drought and suggest solutions which emerge from the above factors and considerations."

#### 4.5.4 Machine Environment

The term ‘machine environment’ in this section will be used to refer to the characteristics of both computer systems and paper-based books. Although there are many practical differences between human-computer interactions and human-book interactions, at an abstract level both book and computer can be considered simply as different artefacts that contain various mappings, affordances and feedbacks (Norman, 1988). This section will review how these mappings, affordances and feedbacks can differ in the ‘machine environment’ of books and computer-based text systems.

##### *Manipulating paper and online text*

Ignoring the fact that hypertext can support a wider array of data formats than paper-based books (e.g. audio and video data), it might be expected that reading ‘plain’ text and graphics online and from paper would be similar. However, O’Hara and Sellen (1997) found several differences between paper and online text when ten subjects were given the task of summarising a 4 page article from a general science magazine. O’Hara and Sellen present their findings under the following three headings:

- **Annotation While Reading**

Four out of five subjects using paper employed some form of note-taking activity. Annotations were made quickly and were interwoven with the ongoing reading. However, only one subject in the online treatment attempted annotation. This subject was only able to annotate the document by customising the toolbar which enabled him to draw boxes around various paragraphs and create other visual notations. However, O’Hara and Sellen (1997) note that the difficulty this subject experienced annotating the online text interfered with the smooth flow of the reading.

- **Movement Within and Between Documents**

“Movement through paper documents was characterised by its speed and automaticity. For example, page turning in the paper condition was often anticipatory, with one hand often lifting a page before it was read, minimising disruption between reading the text at the end of one page and

the beginning of another. That it was so automatic is highlighted by the fact that sometimes pages were turned prematurely.”

*O'Hara and Sellen (1997)*

However, a number of navigation problems were experienced online. System response speed resulted in negative comments from subjects, such as anger and loss of interest. System feedback also resulted in problems. For example, a document did not refresh its display while using the toolbar drag function until after the mouse was released<sup>11</sup>. System response and feedback were exacerbated by the limitations of the input devices used (keyboard and mouse). Controlling a document using one hand resulted in a cumbersome interleaving of activities. Indeed, the underlying GUI paradigm forced a sequential processing of activities.

- **Spatial Layout**

All five subjects in the paper condition exploited the possibility of unclipping the assigned documents so that individual pages could be spatially arranged on the desk before them. The advantage of such spatial flexibility was that it allowed the subjects to extract the structure of the document and to keep each page within easy reach for quick reference. Subjects assigned to the online condition, unlike their paper counterparts, were limited in their spatial flexibility primarily by the field of view offered by the screen. Although two pages could be displayed on the screen at once using window tiling, the text of each document became almost unreadable. To ensure a readable resolution, only part of the page could be displayed. Subjects expressed concern at this problem stating that they found it difficult to gather the contextual information necessary for developing a sense of the text and location.

In a separate study, O'Hara, Smith, Newman and Sellen (1998) investigated student readers' use of library documents. Their goal was to provide a set of recommendations with which to improve digital library technology. They found that physical characteristics can affect study behaviour. For example, one subject admitted that often

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<sup>11</sup> Documents within MS Word 2000 do now continually update while the scrollbar is being dragged. Also, the new wheel-type mice permit vertical scrolling of a document regardless of where the pointer is on the screen.

it is quicker to simply copy a passage of text by hand than go down three flights of stairs, obtain a photocopy card, and then queue for the photocopier. Also, some large, heavy, bound journal volumes were photocopied to avoid carrying the complete volume home.

### *Usability related to system response times*

In addition to the O'Hara and Sellen (1997) issues discussed above, several other researchers have found hypertext response times to be problematic. For example, Pitkow and Kehoe (1996) found that the most widely reported problem (76.5% of responses) from 23,000 users questioned was the problem of web pages taking too long to download. Although Nielsen does not give any specific references he does highlight that every web usability study that he has conducted since 1994 has shown the same thing: "users beg us to speed up page downloads." (Nielsen, 2000, p. 42). Referring to an unspecified paper by Robert B. Miller, Nielsen (2000) lists three primary categories of response time:

- **0.1 of a second** – speed required to give the user the impression that the system is responding instantaneously.
- **1.0 second** – speed required for the user's flow of thought to remain uninterrupted.
- **10.0 seconds** – minimum speed required to ensure that the user's attention remains focused on the dialogue. Users will tend to start other tasks if the system cannot respond within this time.

From an educational perspective Patterson and Egidio (1987) found that decision-making quality was not affected by long or short system response time. However, they reported that subjects found the system with the shorter response time easier to operate and preferable to the system with the longer response time. Although decision making quality was not affected in the Patterson and Egidio study, Ramsay, Barbesi and Preece (1998) found that the response time of the web can affect subjects' ratings of page interest. In an experiment they varied the download times of locally held documents between 2 seconds and 2 minutes. Documents downloading in less than 41 second were

found to be significantly more interesting ( $p=0.001$ ) than pages taking longer than 41 seconds.

### ***Reading speed studies***

Historically, much of the early research in this area concluded that reading from paper was significantly faster than CRT (cathode ray tube) displays (e.g. Gould *et al.*, 1987a). This undoubtedly affected reading efficiency on many of the early hypertext systems that employed non-proportional fonts displayed on a dark background. More recently though, studies have found that when paper and screen formats are similar (in terms of font family, size, leading and polarity) then the reading speed difference is insignificant (Gould *et al.*, 1987b). Muter and Maurutto (1991) also found reading speed was similar between paper and CRT, but that skimming a text to ascertain its main points resulted in CRT being 41% slower than paper. However, although subjects were skimming book text faster, subjects using the CRT were more accurate. The authors suggest a number of possible reasons why text skimming was significantly slower on screen than paper:

1. The CRT condition used longer lines of text (85 characters compared with 60 for paper) which thus require greater lateral eye movements.
2. Speed difference the result of the observed speed-accuracy trade-off.
3. The CRT contained fewer words per page. CRT required approximately 12 pages per story, whereas paper used approximately 5 pages per story. Moving between pages/screen would require a small period of orientation before proceeding again with the task.
4. The results could be specific to the task. Muter and Maurutto (1991) speculate that different results could have been observed if subjects were skimming for specific information instead of skimming to obtain the overall meaning of a story.

It would thus appear that normal reading speeds between paper and modern CRT displays is almost identical. However, the aspect ratio and area of information currently visible using CRT and paper can affect tasks requiring the user to quickly scan for key points or words.

## 4.6 Summary

Every society, for which there is historical evidence, has relied upon information. This information must be created initially, stored somehow, and then disseminated in a suitable form to those who require it. A medium plays a pivotal role in the support of information. It is interesting that even in the field of education, Laurillard (1993) argues that one of the reasons why print media have been used so extensively is not because of any pedagogical advantages, but simply because they are easy to author, print, distribute and use.

As Gaur (1984) posits, there are no special types of literary media, only those appropriate to the current developmental stage of a society. In recent years print media have become less suitable in the support of contemporary information. Cost, information complexity, updateability and flexible of dissemination are all becoming serious problems. One new literary medium which appears to address these new challenges is hypertext, a computer-based system which stores information as a series of nodes and links. Utilising various software layers a hypertext system can offer a number of aids to online reading: indices, search facilities, history lists, and maps. However, the power of hypertext has, to a certain extent, been paradoxical. For example, because the reader does not receive the same tactile cues from a 2D monitor as they do from a paper book, the hypertext system has to employ additional methods of preventing the user from becoming lost within the system. To date empirical research comparing book and hypertext use, especially in education, has been equivocal. With rapid evolution of hypertext functionality and interaction styles it is important to conduct further research to determine how these changes affect usability. As already mentioned in Section 4.6, various individual differences have been found to correlate with hypertext performance. It may therefore be possible to use these psychological measures as usability evaluation 'tools' with which to uncover the 'cognitive-style bias' referred to by Chinien and Boutin (1993). In the next chapter the thesis will explore the rationale behind the chosen experimental methodology used to investigate the utility of using cognitive styles as such 'tools'.

## 5. Rationale behind chosen research methodology

Before discussing the design and implementation of the hypertext system used in the current research (see Chapter 6), it is first necessary to explain the experimental methodology employed.

### 5.1 Evaluation Methodologies

"All research is based on a discipline that shapes and constrains the arguments made and the methods used."

(Monk & Gilbert, 1995)

As the above quotation argues, the specific discipline in which research is conducted will constrain and influence the various methods employed. In this respect the field of Human-Computer Interaction is fortunate in that it utilises a wide array of different methodologies from a number of 'parent' disciplines. For example, computer science has contributed formal methods, psychology has influenced the adoption of experimental psychology techniques within HCI, and sociology has contributed ethnographic work-place methods. Although such a wide variety of different methodologies is advantageous – there are methodologies appropriate for each stage in the development life-cycle – caution must be exercised when selecting one. Lindgaard (1994) categorises a number of specific evaluation techniques firstly by whether they are used during task performance or at any other time, and secondly by whether they are performed in the laboratory or in the field. Mack and Nielsen (1994) use a slightly different categorisation scheme, instead preferring four main ways which they term: automatic evaluation, empirical evaluation, formal evaluation and informal evaluation. Given that both Mack and Nielsen (1994) and Lindgaard (1994) both contain many of the same individual evaluation techniques, it does not matter which classification scheme is used.



### 5.1.1 Automatic Evaluation

Automatic user interface evaluation can be performed reliably by software utilities. The strength of such evaluation systems are that they can be cheaper to administer since they do not require human users, and they may be applied iteratively as a design progresses.

One example of an automatic evaluation program is Sears' (1993) Layout Appropriateness (LA) system. The usability of a user interface layout is calculated by taking the cost (usually the distance) of each sequence of actions and weighting these with how frequently the sequence is performed. A score of 100 indicates that a design layout is optimal for a particular task. Scores less than 100 show that parts of a design are sub-optimal. This numeric scoring thus allows quantitative comparisons to be made between various designs.

A disadvantage of automatic evaluation methods is that they do not scale up to complex highly interactive user interfaces (Mack & Nielsen, 1994), and they often ignore important environmental variables such as user individual differences (see Section 4.6.2) and display ergonomics (see Section 4.6.4).

### 5.1.2 Empirical Evaluation

#### *Applied Experimental Psychology*

Applied experimental psychology is an approach to conducting research which attempts to understand how psychological processes influence computer use in realistic contexts (McCarthy, 1995). Importantly, it is this last point 'realistic contexts' which separates applied psychology from the other schools of psychology such as social, developmental or cognitive. Lindgaard (1994) highlights the importance of deciding what data to record to answer the research question.

#### *Ethnography*

One of the disadvantages associated with experimental techniques is that they artificially simplify situations to concentrate relationships between dependent and independent

variables. Often extraneous variables are removed from the analysis by rigidly defining experimental procedures within an artificial environment (e.g. laboratory). In an attempt to avoid such problems, ethnographic techniques, originally developed in anthropology and sociology, have been utilised by HCI. Although there are a number of techniques under the heading of ethnography, most share the same basic presuppositions: commitment to study activities in natural settings; an interest in developing detailed descriptions of the lived experience; a focus on actual behaviour, not just behavioural accounts; and a concern with understanding the relation of particular activities to the activities that characterise a setting (Blomberg, 1995).

### **5.1.3 Formal Evaluation**

Formal evaluations are made by constructing models of a particular interaction scenario – a type of user operating the system under evaluation. The advantages of formal methods are that no users are involved so costs are reduced and exposes design decisions which might otherwise not be noticed until the system was being implemented (Dix, 1995). This latter advantage can be seen in the use of formal methods to analyse the functionality of the ‘undo’ command. For example, formal evaluation has been used to logically argue why the undo command cannot actually be undone itself. However, the disadvantage of formal evaluations is the high level of expertise required (Dix, 1995).

### **5.1.4 Informal Evaluation**

Informal evaluation refers to a range of different techniques whereby experienced usability experts evaluate a system based on rules of thumb, general skill and knowledge, and the experience of the evaluators (Mack & Nielsen, 1994).

Heuristic Evaluation is one of the more widely used informal evaluation techniques. Each evaluator works through a system (software or paper prototype) and evaluates each aspect of the interaction against a number of usability heuristics. For example, the

wording of menu items, screen text and error messages can be checked with the first of Nielsen and Molich's (1990) heuristics 'Simple and natural dialog'. However, Nielsen and Molich estimate that only 20% to 51% of usability problems can be identified by a single evaluator. Combining multiple evaluators, up to approximately six (Nielsen, 1992), especially 'double specialists'<sup>12</sup>, can significantly improve the number of problems discovered. Heuristic evaluation is a cost-effective technique. Lansdale and Ormerod (1994) present figures showing that the cost of heuristic evaluation compared with empirical usability testing was substantially less but that the benefits (monetary savings) were greater than or equal. However, one of the problems with heuristic evaluation, as highlighted by Nielsen and Molich (1990), is that some of the usability problems discovered by the experts might never actually affect real users interacting with the system.

### 5.1.5 Methodology

There are a number of advantages and disadvantages, in terms of number of users required, time and cost, associated with each of the above evaluation techniques. Although they all assess certain aspects of software usability, Mayes and Fowler (1999) argue that there is a certain usability paradox in the case of educational applications. For example, they posit that the user should be able to effortlessly move to the conceptual level, but then must engage with the underlying meaning. As a concrete example Mayes and Fowler (1999) write:

"For example, while an important usability metric for all other kinds of work is to avoid allowing the user to get lost in information space, in some learning situations it would be beneficial for deep learning for the user to do just that. The learning which would often be associated with navigating out of such situations might not occur with an interface which did too much of the work."

*(Mayes & Fowler, 1999, p. 487)*

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<sup>12</sup> Experts in both usability evaluations and the current task domain.

Given this distinction between user interface usability and educational efficacy, only the empirical evaluation techniques were considered suitable for the current research. Since the non-empirical techniques do not employ real users, evaluating which interfaces are educationally most effective from those most operationally efficient could be difficult.

Originally, when the experiments reported here were being planned, it was the intention to award marks that would contribute to students' overall grades. The rationale behind this was to act as an incentive with which to motivate students and thus be more representative of typical real-world use of hypertext. After all, if hypertext becomes fully established as a dominant educational medium, then students' marks will to some extent be related to their use of the medium. However, in discussions with colleagues it was highlighted that there were a number of ethical issues being overlooked. For example, given that performance between the book and hypertext groups was likely to differ, those assigned to the poorer performing group would be at an unfair disadvantage. To solve this problem the marks were only used for the purposes of the current research, but to maintain motivation all students completing all experimental sessions were entered into a prize draw. Two students, one from the book group and one from the hypertext group, were selected at random to receive a cash prize.

A second technique which was considered but ultimately rejected was the use of *pattern notes*, a cognitive mapping technique. Given that learning is a process of assimilating and accommodating new information into the learner's existing knowledge structures, being able to 'inspect' this process is a valuable method of assessing learning. Some traditional techniques, such as written exams, are often criticised for being more a test of memory than cognition. Although Jonassen (1987) discusses several practical applications of pattern notes, such as its use as an evaluation and planning tool, remediation, advanced organizer and task analysis, the technique was not considered appropriate for the current research. Given the limited time available in which to conduct the empirical aspects of the research it was unlikely that subjects' cognitive structure would change sufficiently to show any appreciable differences when assessed using pattern notes or similar techniques. Ideally pattern notes could be used once at the

start of a course and once at the end as a method of assessing changes in subjects' knowledge structures.

## 5.2 Research Hypotheses

A general aim of the research, as already discussed in Section 2.1, was to determine the current educational potential of hypertext compared with books. Although some studies of hypertext have found it to be less efficient than books in terms of the time required to complete specific tasks, and less effective in terms of the quality of these completed tasks, with rapid developments in computer hardware facilitating new high resolution screens and fast GUI-based operating systems, a reappraisal seemed timely. The first hypothesis can thus be stated:

1. Hypertext users will perform information retrieval tasks significantly faster than book users.

The rationale behind this hypothesis is that the speed with which a hypertext system can execute a full-text search of its contents is likely to be faster than an individual manually using the index of a book (Landauer *et al.*, 1993). This is likely to be especially true for information that has not been explicitly indexed, or which has been indexed under various related terms (Lehto *et al.*, 1995).

Although the efficiency is expected to be better than a book, effectiveness in terms of task completion quality is not likely to be significantly different. Quality can be objectively measured in terms of accuracy in completing basic information retrieval tasks. Using such a definition of quality, the second hypothesis is:

2. Hypertext users will not be more accurate than book users when engaged in information retrieval tasks.

Locating specific pieces of information is a vital skill, but often in higher education students are required to review and synthesise information in essay format. Many early

advocates of hypertext suggest that it is in this role that hypertext has the largest part to play. However, in the context of the current research it is not expected that the quality of essay writing will be higher using hypertext than books because of the limited exposure to the new capabilities afforded by hypertext. As Burbules and Callister (1996) posit, learning to 'hyperread' is as complex and challenging a task as learning to read in the first place and may involve unlearning certain habits associated with reading linear texts. Thus, the third hypothesis made here can be expressed:

3. The quality of essays in terms of concepts presented will not significantly differ between Book and Hypertext users.

The hypotheses stated so far have been expressed without specific regard to any individual differences subjects may bring to the learning. As was discussed in Chapter 3, various individual differences have been found to be important variables in computer-based learning environments. However, several of these significant findings occurred when various experimental conditions were specifically designed to match or mismatch individual differences. Also, it would appear that various cognitive individual differences interact not only with the properties of the subject matter but also with the properties of the medium. Spatial ability and field dependence have both been found to be significant factors in predicting performance in using hypertext systems. The aim of the current research was to determine whether these two differences in particular still remain important when the systems are *not* optimised for these styles.

4. Significant performance differences will not correlate with spatial ability or field dependence/wholist-analytic style in a modern hypertext system containing a variety of different navigational structures and functions.

The rationale behind this hypothesis was that in hypertext systems with sufficiently rich functionality users can often select (see 'Selecting' in Section 3.5) different tools which suit their preferences. For example, as already mentioned in Section 4.5.2, although Leader and Klein (1996) did find significant differences between cognitive style and specific hypertext navigational tools, they also found that the differences disappeared in

the experimental condition utilising all three different tools: browser, index/find and a map. In relation to supporting cognitive styles such as field dependence this will involve including navigational tools permitting a broad overview of the hyperspace, such as maps and tables of contents, for field-dependent individuals and tools for more focused enquiry, such as indices and search routines, for more field-independent individuals. Similarly, associative links would enable individuals with higher spatial ability to fully explore the hyperspace, while pop-up nodes displaying references or glossary terms would minimise the spatial cognitive load for individuals with less spatial ability.

### 5.3 Problem Domain

As discussed in Chapter 4, hypertext has been applied to a diverse range of applications: information retrieval, decision support, entertainment, writing and education. It has also been used to represent a wide variety of different subject matters including: chemistry (Landauer *et al.*, 1993), Newtonian physics (Gill & Wright, 1994), Greek literature (Marchionini, & Crane, 1994), second language learning (Lui & Reed, 1995), transfusion medicine (Jonassen, Ambruso & Olesen, 1992), history (Britt, Rouet & Perfetti, 1996), art (Velthoven & Seijdel, 1996). However, the problems associated with each of these domains can be substantially different from one another. Thus, before deciding upon a particular hypertext system to use in the next chapter, it was essential to establish the precise nature of the problem domain to be studied.

McKnight, Dillon and Richardson (1991) proposed that the main variables that affect hypertext performance include the user group, subject matter and the tasks the system is designed to support. These three variables are discussed below.

#### ***Subject Matter***

As we saw in Chapter 2, there are a number of problems affecting the whole of higher education, such as financial pressure and increased student numbers. Academic disciplines may also exhibit their own additional problems. Notwithstanding that nearly

every domain becomes more complex when studied at more progressively advanced levels, some fields have an inherent complexity which stretches the use of traditional media such as paper. Although, well understood conceptually at undergraduate level, the sheer scope and interconnectedness of domains such as medicine and law, make these fields difficult to represent using paper and traditional media. Other fields, such as computing, which are changing considerably each year, pose problems concerning the updateability of their curricula. One particular field, Human-Computer Interaction, would seem to exhibit both of these problems – progress within the field is rapid, and there is an inherent complexity derived from its multi-disciplinary heritage.

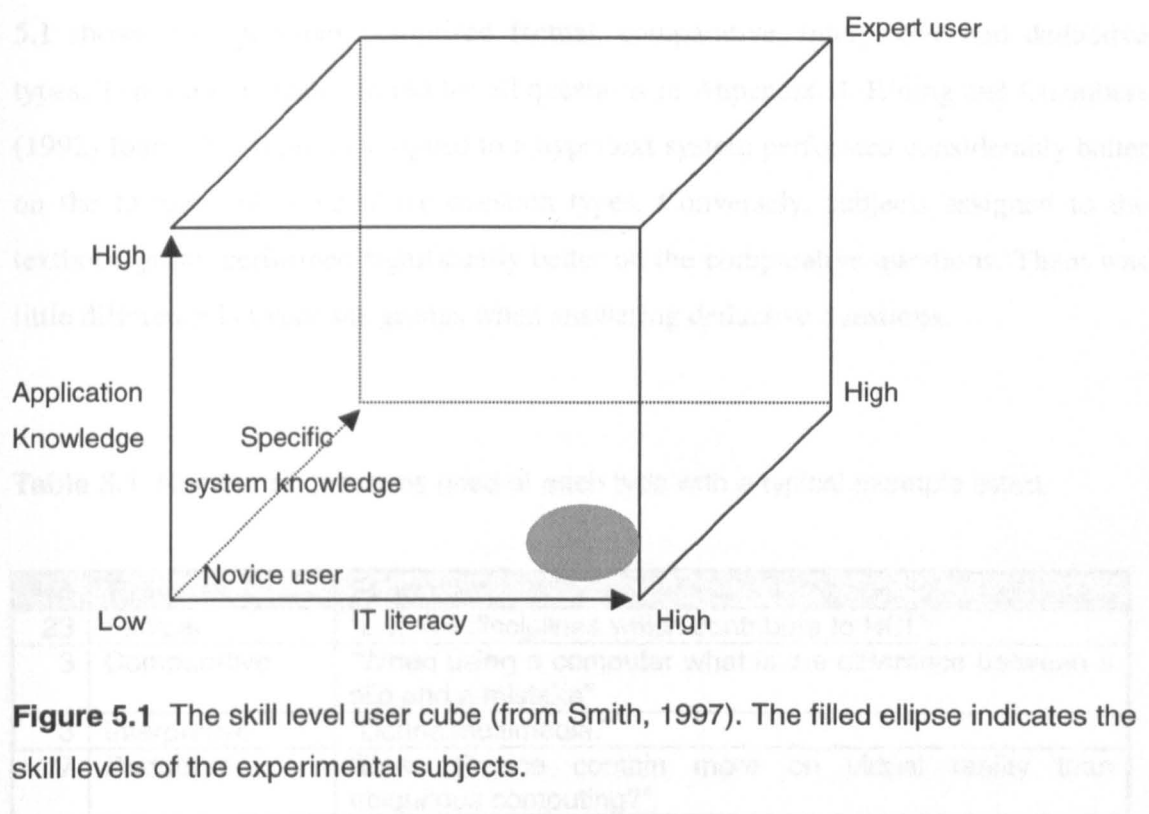
### *User Group*

Obtaining test subjects for any empirical evaluation is notoriously difficult. Choosing the domain of Human-Computer Interaction allowed the use of students studying this subject matter at Napier University where the author of this thesis was working. In particular 59 students in total completing either an MSc in Information Systems or an MSc in Software Technology were selected. To avoid any methodological problems the research was conducted at the beginning of the semester in which they studied HCI. The reason for this was to try and minimise differences in the amount of HCI knowledge the subjects possessed. As the skills cube in Figure 5.1 shows, most users should have relatively high IT skill, low systems specific knowledge in the case of the hypertext system used<sup>13</sup>, and low HCI application knowledge. One of the recommended textbooks for these subjects was *Human-Computer Interaction* by Preece *et al.* (1994). As such it seemed a good choice for use as the experimental text. Its suitability for conversion into hypertext will be discussed in the next chapter.

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<sup>13</sup> Although specific hypertext skill is likely to be low, subjects should have well developed book skills at postgraduate level.





**Figure 5.1** The skill level user cube (from Smith, 1997). The filled ellipse indicates the skill levels of the experimental subjects.

### Tasks

The third important variable in hypertext interaction, as outlined by McKnight, *et al.*, is task type. As was discussed in Section 4.6.3, there is empirical evidence that this is indeed an important aspect of such interaction. However, the term ‘task’ is rather broad in meaning and can refer to a number of different specific activities. For example, Riding and Chambers (1992) employed four types of task to compare book and hypertext performance: factual, interpretative, comparative and deductive questions. Using a combination of these question types, the current research was conducted over two task sessions.

The first set of tasks comprised 35 closed questions (see Appendix B). The emphasis in this first session was to investigate primarily the information retrieval speed of book and hypertext versions of *Human-Computer Interaction*. The difficulty of the questions increased gradually throughout Task 1 in an attempt to ascertain whether Book or Hypertext shows any particular advantages past a certain level of difficulty. In addition to this rise in difficulty, a number of different types of questions were used. As Table

5.1 shows, the questions comprised factual, comparative, interpretive and deductive types. Types are indicated in red for all questions in Appendix B. Riding and Chambers (1992) found that subjects assigned to a hypertext system performed considerably better on the factual and comparative question types. Conversely, subjects assigned to the textbook group performed significantly better on the comparative questions. There was little difference between the groups when answering deductive questions.

**Table 5.1** Number of questions used of each type with a typical example listed.

No	Type	Example
23	Factual	"List five disciplines which contribute to HCI."
3	Comparative	"When using a computer what is the difference between a slip and a mistake"
3	Interpretive	"Define multimedia."
7	Deductive	"Does Preece contain more on virtual reality than ubiquitous computing?"

While the questions generated for the first task session were designed to determine the relative information retrieval speeds between the two experimental media, it could be argued that such questions are rather contrived and would not be typical tasks in 'normal' learning situations. Thus, a second set of tasks was devised, with greater emphasis on application once the information was found. To do this, a fictitious scenario was developed around which four open questions were set. All four questions in this case were deductive in nature (see Appendix C). These questions were developed to require subjects to gather information from several different parts of the book and compare and synthesize the information. For example, while *Human-Computer Interaction* covers both software development life-cycles and personal digital assistants (PDAs), both mentioned in the scenario, it does not discuss the two together.

## 5.4 Variables

As stated in Section 1.2, Lowe and Hall (1999) provide a broad definition of hypertext usability. A hypertext system must facilitate access to and manipulation of information. Using such a definition, it is important to ask which aspects of the human-computer interaction with a hypertext are likely to elicit the largest differences in the achievement of the above goals. Having already selected a subject matter, user group and tasks in the previous section, it is necessary to discuss which variables to measure.

Although definitions of hypertext vary, all implicitly or explicitly emphasise structure through the creation of links between nodes. Rather than concentrating on a description of various features, Lowe and Hall (1999) present a goal-based definition:

"To support (using the associative relationships between information sources) the carrying out of actions which result in the identification of appropriate information (with appropriateness being based on a given set of contextually defined criteria)."  
(Lowe and Hall, 1999, p. 42)

Referring back to the individual differences reviewed in Chapter 3 and previous research cited in Section 4.5.2, it appears that two categories of psychological differences may be important in a usability analysis of hypertext: spatial ability and cognitive style.

### 5.4.1 Independent Variables

#### *Spatial Ability*

Spatial ability, as mentioned in Section 3.2, has been found to relate to significant differences in performance when using a database (Benyon, 1993), hierarchical file system (Vicente, Hayes & Williges, 1987) and various hypertext systems (McGrath, 1992; Höök, Sjölander & Dahlbäck, 1996). As is to be expected, in general those subjects with higher spatial ability performed the tasks faster than subjects with lower

spatial ability. With the selected text for the current study, *Human Computer Interaction*, utilising a clear hierarchical structure, coupled with frequent inter-sectional references, spatial ability appears to be a useful measure with which to investigate usability. The Shapes Analysis Test was used to assess spatial ability, this test will be discussed further in Section 7.2.2.

### ***Cognitive Style***

As well as spatial ability, certain cognitive styles have also been found related to structure-oriented tasks. Witkin *et al.* (1977) report that individuals who have a field-dependent cognitive style find it harder to restructure or to impose structure on learning material than those individuals who have a more field-independent style. Although Witkin *et al.* (1977) state that when the material to be learned is already organized, field-dependent and field-independent learners are not likely to differ in their learning, there are other important factors. For example, field-dependent individuals have been found to favour a spectator approach to concept attainment whereas more field-independent individuals prefer a hypothesis-testing approach. Although *Human Computer Interaction* is already a well-structured book, it could be argued that the strategic 'spectator' versus 'hypothesis-testing' approaches adopted by different individuals may have important implications when deciding how to navigate through a hypertext. As already mentioned, in Section 4.2.1, Aust, Kelley and Roby (1993) found that users of a hypertext-based dictionary looked up more definitions than users of a paper-based dictionary. However, it would be interesting to investigate whether there were any significant navigational differences based on cognitive style. Two measures of cognitive style were used, Group Embedded Figures Test (GEFT) and Cognitive Styles Analysis (CSA). Both tests will be discussed further in Section 7.2.2.

### ***Other variables***

In addition to cognitive style and spatial ability that were the primary focus of the research, a number of other variables were measured in case they adversely affected the main measures. As will be reported in the discussion part of Experiment 1 (see Section 7.4.2), Mead, Spaulding, Sit, Meyer and Walker (1997) and Westerman, Davies,

Glendon, Stammers and Matthews (1995) both found significant differences in task performance related to age.

Gender is another variable which is easy to record without specialist tests. As already mentioned in Section 4.5.2, Ford and Chen (2001) found a significant interaction between gender and performance of subjects in a matched experimental condition.

#### **5.4.2 Dependent variables**

As mentioned above in Section 5.3, two experimental tasks were devised. The first, which aimed to record the information retrieval speed of each medium, measured: 1) total number of questions answered, 2) number of questions correct, and 3) resulting percentage accuracy. Quantitative measures were used, in a similar way to the studies by Leventhal, Teasley, Instone, Rohlman and Farhat (1993) and Lehto, Zhu and Carpenter (1995), so that direct comparisons could easily be made between book and hypertext performance (Nielsen, 1993).

The second task, which was designed to assess the ability of book and hypertext to support application of information, measured: 1) total number of words written for each question, and 2) mark awarded for the quality of each answer. Again, quantitative data was recorded to facilitate ease of comparison between the two experimental media.

A questionnaire (see Appendix D), issued one week after both experimental tasks had been completed, was designed to capture further background information about the subject and his or her attitudes towards the medium they were assigned to. A range of quantitative and open-ended qualitative questions were used.

## 6. Hypertext Design and Implementation

"But hypertext is more than just a new way of organizing existing information; it influences the kinds of information it organizes."

*Burbules & Callister, 1996*

In Chapter 4 the theoretical concept of hypertext was discussed together with a review of some of the features supported by modern hypertext systems. The current chapter takes this broad review of hypertext and applies it to the specific problem of designing a hypertext application to support post-graduate learning in higher education. The first half of the chapter reviews some of the system alternatives available to develop a hypertext system, while the second half concentrates on the specific issues involved in converting the text Human-Computer Interaction (Preece *et al.*, 1994) into a WinHelp hypertext implementation.

### 6.1 System alternatives

A review of the hypertext literature, together with practical experience of several hypertext systems, suggested that there were three approaches to creating a suitable hyperdocument:

#### 1. Custom-built

Building a system from scratch would provide maximum flexibility in terms of design, but would have required too much development time. In addition, before the evaluation of such a system in an educational context, lengthy debugging and usability testing would have been required to establish the reliability and ease of use of the software. Since the goal of the research was to evaluate the potential of hypertext to support education, poor usability or system reliability could have adversely affected the results.

## **2. Application Supported**

Several 'non-hypertext' applications in recent years have included basic node and link facilities within their standard functionality. While it would be difficult to utilise the hypertext functionality of some of these applications (e.g. Lotus Organizer, Concise Oxford Dictionary on CD-ROM), others, for example MS Word 97, would allow the creation of simple hyperdocuments. While a hypertext built in such a system would avoid the disadvantages of the custom-built option, it would still lack some of the more sophisticated hypertext facilities such as pop-up nodes and multiple windows.

## **3. Dedicated Hypertext**

Since the popularity of Apple's HyperCard system (see next section), a number of other hypertext environments have been released. Instead of supporting the creation of paper-based documents, spreadsheets or databases, these hypertext systems are designed primarily to support the creation of online hypertext documents. The advantage of using a commercial dedicated hypertext system is that its functionality has been specifically designed to support hypertext documents and it has been debugged and tested. For this reason it was decided to use a dedicated hypertext system for the current research.

The following sections provide a brief review of five commercial hypertext systems which were considered as candidates. Since all of them provide basic hypertext functionality such as node/links and history mechanisms, the discussion here will be limited to their main advantages and disadvantages.

### **6.1.1 HyperCard**

HyperCard, one of the more famous hypertext systems, was, ironically, not originally developed as a hypertext environment. Bill Atkinson, its author, developed the system as a graphic programming environment (Nielsen, 1995). However, its card and stack

metaphor with basic link functionality made it an ideal rapid prototyping/hypertext environment. It was distributed free with the early Macintosh computers, thus allowing many people to explore its facilities who might not otherwise have attempted hypertext authoring.

### ***Advantages***

- **Cost**

As already mentioned, its biggest advantage initially was the fact that it came bundled free with the early Apple Macintosh computers. Even later when Apple charged for HyperCard, the reader was still provided free (much like the Adobe Acrobat Reader familiar today).

- **Programmable**

A second major advantage of HyperCard, which is probably why it has been used in so many hypertext research projects, is the inclusion of an easily learned high-level programming language, HyperTalk. The use of HyperTalk within HyperCard offers two primary advantages: 1) it extends the basic functionality of HyperCard thus allowing a wider variety of problems to be solved, and 2) it permits the creation of computational hypertext. This latter use of HyperTalk allows programmers/authors to create hypertext which dynamically renders content to the user in real-time under program control (Nielsen, 1995).

### ***Disadvantages***

- **Platform Dependent**

Although Apple Computers is once again a profitable business following the introduction of the latest iMac computer range, Apple computers still only occupy a small market when compared with the IBM compatibles and various UNIX platforms. Aside from the home market which is supporting the iMac, the more powerful Apple computers tend to be used in well-defined business niche markets such as desktop publishing, graphic design or music recording. Educationally, apart from some use in secondary education and specialist multimedia labs, Apple



computers are not used very much. Thus, although the primary aim of the research reported in this thesis was to evaluate the usability of educational hypertext, and so theoretically platform should be unimportant, from a pragmatic perspective it made sense to choose a system which would run on the majority of computers used in higher education.

- **Development/Maintenance Problems**

Notwithstanding HyperCard's rather small market, due to hardware platform, there are a number of other fundamental problems. For example, because HyperCard uses cards to contain the content of each node, the creation of moderately large hypertext systems (i.e. a few hundred nodes and upwards) is time-consuming. Special background cards can be created which act as masters applied to all other cards, but large hypertexts will require hundreds of individual cards to be created. Also, as mentioned in Section 4.4.4 above, the restriction of card size to the current screen resolution can present problems when authoring nodes with a large amount of content. The card-oriented approach can, as Nielsen (1995) argues, possibly lead to maintenance problems. For example, a link anchor is created by drawing a rectangular 'hot spot' over the text or graphic which will form the link. Problems can occur when the underlying text or graphic is changed but the hot spot size and location remain the same. Similar problems can also be encountered when using Adobe Acrobat (see below) to create PDF documents.

### **6.1.2 Adobe Acrobat – Portable Document Format (PDF)**

Adobe Acrobat was developed primarily to support the cross-platform sharing of electronic publications. To this end, Acrobat readers have been developed for all versions of MS Windows, Apple System 7/8 and several flavours of UNIX.

## *Advantages*

- **Platform Independence**

As already mentioned, Acrobat Portable Document Format (PDF) files can be read by readers on all main microcomputer operating systems. The format is also gaining support for use on the web with plugins for both Netscape and Internet Explorer. The principal advantage of PDF over HTML as a web document format is the former format's much greater visual layout support. Since PDF files are created from Postscript source files, virtually any type of paper-based document can be converted with almost no loss of visual formatting. When created, the author of a PDF file can control whether Acrobat will substitute similar fonts or use font embedding. If the former method is used then a PDF document written on the PC and using Arial font might be displayed on a Macintosh system using the font Helvetica which is a very similar sans-serif typeface. However, if font embedding is selected then additional data is included within the PDF file to help the reader render the typeface even on computers that do not have the font installed. The advantage of such tight typographical control is that, for example, a word at the bottom of the second column remains in this location on a PC, a Macintosh and a UNIX system. Although HTML is cross-platform, the presence of different fonts on various computer platforms determines the specific line lengths and word wrappings of a particular document. Even the latest version of HTML (version 4.0) with its extensions of Cascading Style Sheets and DynamicHTML cannot compete against the sophisticated layout capabilities of PDF.

In addition to its primary document reproduction capabilities, Acrobat also supports basic hypertext functionality such as: links (intra-document and WWW), bookmarks, thumbnails, dynamically expandable table of contents and backtracking.

## ***Disadvantages***

- **Limited Copy Support**

Although PDF appears to offer several advantages over HTML it is not without its disadvantages. Within an educational environment where students would be expected to take notes and copy sections of text, the ability to copy a sentence or paragraph would be fairly important. However, until version 4.0, the Acrobat reader has only been able to copy one line at a time. Thus, to include a three line direct quotation in an essay, a student would have to execute three separate copy and paste actions – quite a usability problem.

- **Page-Based**

Portable Document Format, as its name suggests was initially developed as a way to electronically store and render what were originally paper-based, or certainly paper-like, documents. However, as Bolter (1991) suggests, “...the page itself is not a meaningful unit of electronic writing.” (p. 3). The basic problem is that the vast majority of academic textbooks and papers are portrait in orientation, whereas most computer displays are landscape in orientation. Thus, what appears as a single ‘whole’ page on paper, requires a certain amount of scrolling. Typically, if the document is expanded to fit the current screen width, a page will require roughly two vertical screen’s worth of display space. This coupled with the frequent use of intra-document references commonly seen in paper, such as ‘see page 8’, can create unexpected usability problems in the electronic environment. For example, if two screens are required for each physical paper page, what does ‘page 8’ refer to, the top of the page or the bottom half? Therein lies the potential disadvantage of trying to adapt a primarily electronic paper system into a purely hypertextual system which has no roots in the traditional paper-based past.

- **No Index**

Another bizarre aspect of a document system with its roots in paper-based sources is the lack of a conventional index. A table of contents which can dynamically expand or contract various levels of the hierarchy is available, but it appears odd

that there is no automatic support for indexing. Of course a paper-based document which did have an index could be converted and each index entry converted into a hyperlink pointing to the appropriate part of the document. However, this is time-consuming work to complete for a paper-based table of contents, much less a full index. Indeed, it is interesting to note how many academic papers which have been converted into PDF (a matter of a few seconds) have no additional hypertext facilities provided (much more time consuming), not even clickable page numbers in the converted paper-based table of contents pages or the use of Acrobat's in-built dynamic contents list. Many PDF authors do not even bother to go through and create hyperlinks to make clickable email addresses or web URLs.

### 6.1.3 HTML

Hypertext Markup Language (HTML) first started to be extensively used around 1991 when the World Wide Web (WWW) was created. HTML provided an efficient way to specify web pages given the bandwidth limitations of the Internet.

#### *Advantages*

- **Cross-Platform Support**

The biggest advantage of HTML is undoubtedly its cross-platform compatibility. A body known as the World Wide Web Consortium (W3C) which comprises a board consisting of some of the most influential IT companies (Microsoft, Apple, AT&T), establishes and ratifies new standards for this markup language. When a new specification (version) has been established, it is a relatively simple task to develop web browsers for each platform to support this new standard. However, because of the current limitations of even the latest version, many web browsers support their own proprietary extensions to the standard.

- **Automatic Footprint Capabilities**

Another advantage of HTML, when compared against WinHelp, Adobe Acrobat and DynaText, is its inclusion of a footprint system. By default, unvisited links are rendered in a royal blue colour, whereas after the user has visited an area the link changes to a purple colour. The HTML standard documents how the unvisited and visited link colours can be specified, but it does not precisely define what object should be counted as being visited. For example, as already mentioned in Section 4.4.6, Netscape Navigator treats the *links* as visited whereas MS Internet Explorer uses visited *nodes* to control footprinting.

### ***Disadvantages***

- **Slow Speed**

Slow speed is a disadvantage of the web *per se* rather than HTML, but the web is one of the slowest hypertext systems, especially compared with 'stand-alone' systems running from a local disk system or local-area network (LAN). The problem stems from the architectural client-server model of the internet. When a user clicks on a link in a web page the web browser software connects to a local web server (Internet Service Provider or company server), this server then establishes which server stores the requested page and sends a request to it. The system slows down, like physical road networks, when there is too much traffic on the system. If too many users request pages all from the same server then they have to wait until other users have their requests satisfied. The problem can be compounded by media types which are bandwidth hungry. Downloading graphics, animations, sounds/music and WebTV/Video can be very slow indeed, especially for domestic users with slow network connections.

However, HTML can still be slower than alternative hypertext systems even when executed from a local file store. The reason for this lies in the way in which it stores non-textual data. While most modern applications store text and graphics together in a single data file, HTML data files can only contain text. Any alternative data sources, such as an image, have to be stored in a different file (e.g. Compuserve

GIF or JPEG) format and then linked to the HTML file using special image tags. The disadvantage is that when an HTML page is rendered by the browser, all these separate files have to be opened, read and closed individually. This places a large burden on the web server/operating system handling all these files. The scale of the problem can be appreciated when some of the current business web sites, such as Sony or Pioneer, can use up to twenty different images on a single web page.

- **Maintenance Problems**

In addition to the issue of speed, such a large number of individual files for each logical web page also creates maintenance issues. Large numbers of files need to be backed up by webmasters/designers and moving whole sites between servers/disks can be problematic. While some of the 'File 404: Not Found' error messages are caused when a site links to another site which no longer exists, there are also a large number of such errors which can occur *within* a company's web site. While there are some automated link checking tools available, they are not perfect. The author of this thesis has used some utilities which report problematic links when in fact, after a manual check, no problem existed.

- **Visual Page Rendering**

Somewhat less of a problem than the aforementioned maintenance problem, but annoying to users and designers alike, is the problem of visual page rendering. For example, two different browsers (e.g. Netscape Navigator, MS Internet Explorer) will often display text in different sizes and use subtly different shades of colour. Such visual changes makes it difficult for a designer, for example, to place a button or image at the bottom of the screen.

- **No Index**

HTML does not currently support an index type tag. Although simple indexes can be created using standard links, if the material is expanded or changes node then the index will not be updated automatically. The lack of an automatic update of such index links would create complex maintenance issues for large web sites.

- **Limited Search Capabilities**

At the start of the current research project searching within a specific web site was rare, only a few general web search engines existed. Four years on and although it is now possible to search many corporate and some educational web sites, there are few standard search functions. For example, the syntax employed to specify boolean search logic can differ between search facilities. Even among the general Internet search engines, the set of web sites indexed can differ considerably.

#### **6.1.4 Windows 95/NT Help Engine**

Many novice users may think that MS Windows help files are embedded inside the applications they are designed to support. However, the reality is that each application uses one, or possibly a collection, of help .HLP files. When a user pulls down the 'Help' menu and selects 'Contents and Index' the application calls the relevant help file. In the background, Windows determines that .HLP files require WINHELP.EXE to run and starts up the help engine (reader). It is precisely because help files are not actually part of their parent applications, that hypertext authors can use the Windows Help engine to display 'stand-alone' hypertext applications. The advantages and disadvantages discussed below apply to the version of the help engine which is supplied with Windows 95 and NT 4.0.

##### ***Advantages***

- **Price**

WinHelp bundled free with Windows 95/NT, it is also installed automatically so that it can display the help files of 'typical' software applications. Although the Adobe Acrobat reader discussed above is also available free of charge, users are still required to download and install it. So WinHelp is a very accessible facility for users.

- **Speed**

Unlike HTML, WinHelp systems use a single file to contain the main text and graphics, one file for the table of contents and another one for the full-text search index. Excluding the table of contents and the search file, there is only one file which is being read by the help engine. Since moving between various pages in the help system only requires moving an internal data pointer, instead of opening multiple files, WinHelp runs inherently faster than HTML.

- **Ease of Distribution**

A second advantage of WinHelp is ease of distribution. Only three files need to be copied to the installation platform (PC or server). As we saw above, complex web sites implemented in HTML often require several hundred individual files and a suitable directory structure to store these files. This large number of files can cause problems when maintaining and moving web sites. Often, in sites without rigorous testing, pages can download that are missing one of the associated graphics files. Using WinHelp avoids these difficulties.

- **Table of Contents**

The WinHelp engine supports an expandable/collapsible table of contents. As was discussed in Section 4.4.6, Chimera, Wolman, Mark and Shneiderman (1994) found expandable/collapsible tables of contents were as fast as multi-pane tables of contents and significantly faster than a single scrolling table of contents. However, the specific implementation of expandable/collapsible table of contents in WinHelp does have a few limitations. For example, there is no automatic checking that the table of contents accurately reflects the structure of the main help file. While unlikely to be an issue for a research project, the lack of such automatic facilities to synchronise the table of contents and the main help file could lengthen the amount of time required for maintenance. A second limitation is the rules imposed for the hierarchy. For example, each parent level may contain no actual content itself, only links to children which are either parents themselves or which hold actual content. In practice this design means that the structure of some paper-based books may



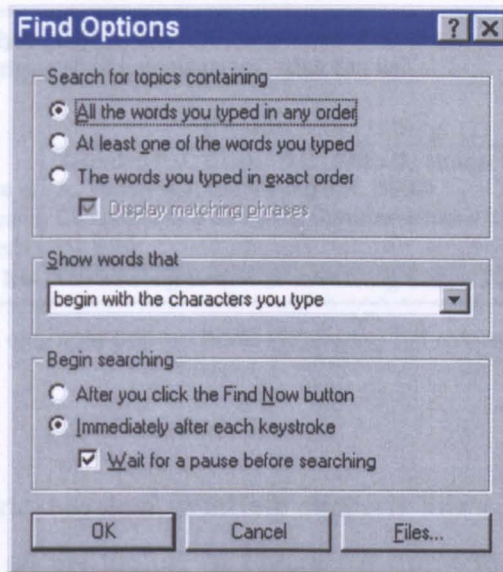
have to be altered slightly, as will be discussed in further detail below in Section 6.2.3, to be accommodated by WinHelp.

- **Index**

Unlike the table of contents, which is not automatically checked against actual content, the index is created from special footnote tags inserted into the help file source code before compilation. The advantage of using such footnotes for each index entry is that if a new one is added or an old one deleted, then the index is updated automatically the next time the system is compiled.

- **Searchable**

In addition to the index, which has to be created by hand using footnotes, WinHelp also automatically provides full-text searching capabilities. As Figure 6.1 shows, WinHelp supports a number of search options. The first, “All the words you typed in any order” provides a simple boolean AND between all search terms, the second option provides a simple OR operation, and the third option matches keyword phrases. However, unlike DynaText (see Section 6.1.5 below), WinHelp does not employ stop word lists. Thus, entering search terms such as ‘a’, ‘the’ or ‘that’ will return hits matching a large percentage of the hypertext. Also, WinHelp does not highlight the occurrence of the search terms when displaying the resulting nodes.



**Figure 6.1** The 'Find Options' dialog box used by WinHelp to control full-text searching.

- **Pop-up nodes**

There are often occasions when an author wishes to include important information, but at the same time does not want to interrupt the smooth flow of the text. Traditional examples of such information in books could be glossary terms, references and appendices which are usually included at the end of the book. Hypertext, with its emphasis on separate nodes and links, is well equipped to support such ancillary information. Most window-based hypertext systems allow multiple windows to be displayed, but WinHelp includes a special pop-up node window type which can be seen in Figure 6.2. Pop-up nodes are indicated by the presence of a dotted underline instead of the usual solid underlining of links. As can be seen in Figure 6.2, the pop-up node window is different from a standard window: it has a shadow and it does not contain a title or any of the standard minimize, maximize or close options. Instead, pop-up nodes are designed to support reference type information which is consulted briefly and then discarded. A single click anywhere on the screen, including the pop-up node itself, will close the pop-up window. This device is very convenient for readers, who can refer to references, footnotes and such like, without losing their current place in the text.



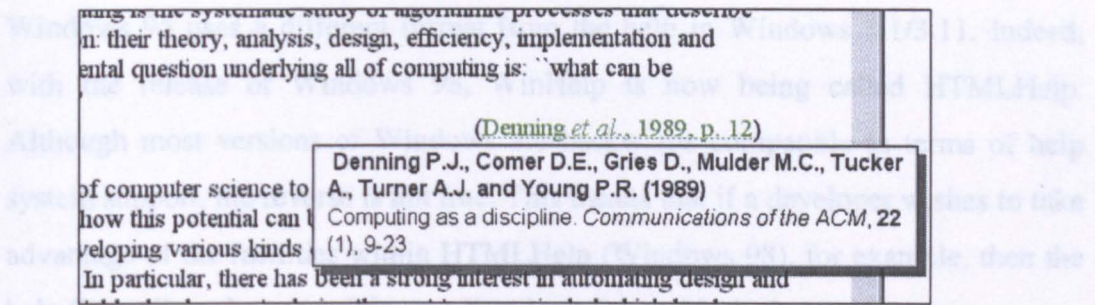


Figure 6.2 An example pop-up node displaying full reference details.

- **Linear Sequence**

Unusually for a hypertext system, WinHelp supports linear sequences. The double left and right arrows on the toolbar in Figure 6.3 move to the previous and next nodes in the system respectively. While the inclusion of a linear path could be questionable for a hypertext system built from scratch, its inclusion is useful for linear paper-based documents which are converted into hypertext format. Special footnotes are used in the WinHelp source files to control which nodes are included in the linear sequence. Altering one of these footnotes automatically updates the sequence the next time the system is recompiled.

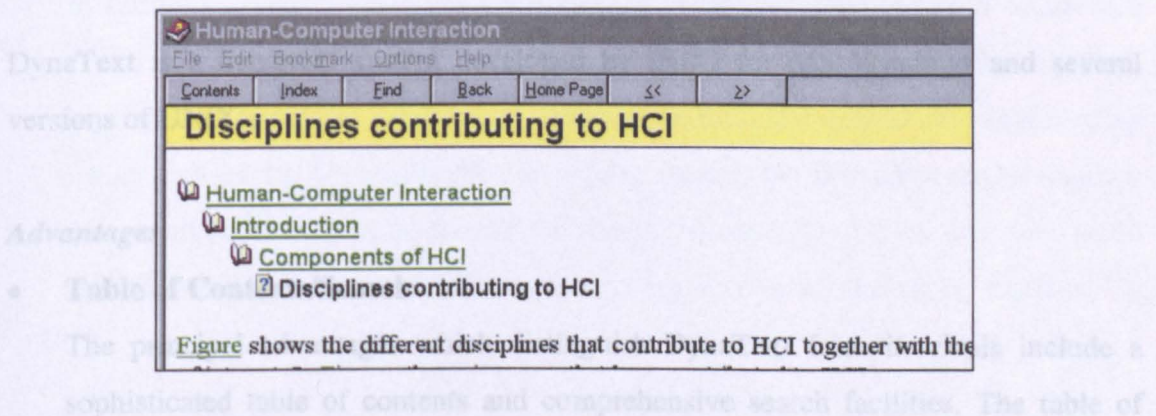


Figure 6.3 Previous and Next sequence buttons are shown at the right end of the toolbar.

### Disadvantages

- **Platform dependent**

A disadvantage of WinHelp is its platform dependence. Not only is it restricted to Microsoft Windows platforms (e.g. 3.1, 3.11, 95, 98 and NT), but it is also restricted to particular versions. For example, WinHelp 4.0 which is part of

Windows 95 uses a different format from the help in Windows 3.1/3.11. Indeed, with the release of Windows 98, WinHelp is now being called HTMLHelp. Although most versions of Windows are backwards compatible in terms of help system support, the reverse is not true. This means that if a developer wishes to take advantage of the facilities within HTMLHelp (Windows 98), for example, then the help file will not be accessible on a Windows 3.1 or 95 platform.

- **No Footprints**

Unfortunately, unlike the HTML browsers, WinHelp does not support footprinting<sup>14</sup>. While it is possible to display a list of previously visited nodes using the 'Display History Window' option, the user has to scan a potentially long list of visited nodes. In contrast, when browsing on the web it is easy to see what colour a link anchor is and to determine if the node has been visited or not (notwithstanding Netscape and Internet Explorer browser differences).

### 6.1.5 DynaText

DynaText is a hypertext system developed by INSO for MS Windows and several versions of UNIX.

#### *Advantages*

- **Table of Contents/Search**

The principal advantages which distinguish DynaText from its rivals include a sophisticated table of contents and comprehensive search facilities. The table of contents, seen on the left side of Figure 6.4 is noteworthy for three main reasons. Firstly, it remains constantly visible as a navigation aid, to reduce disorientation in hyperspace. The width of the table of contents, like most HTML frames on the web, can be resized to suit users' preferences and the current screen resolution. Secondly, it is also fully linked to the larger 'content' pane on the left. The section currently

---

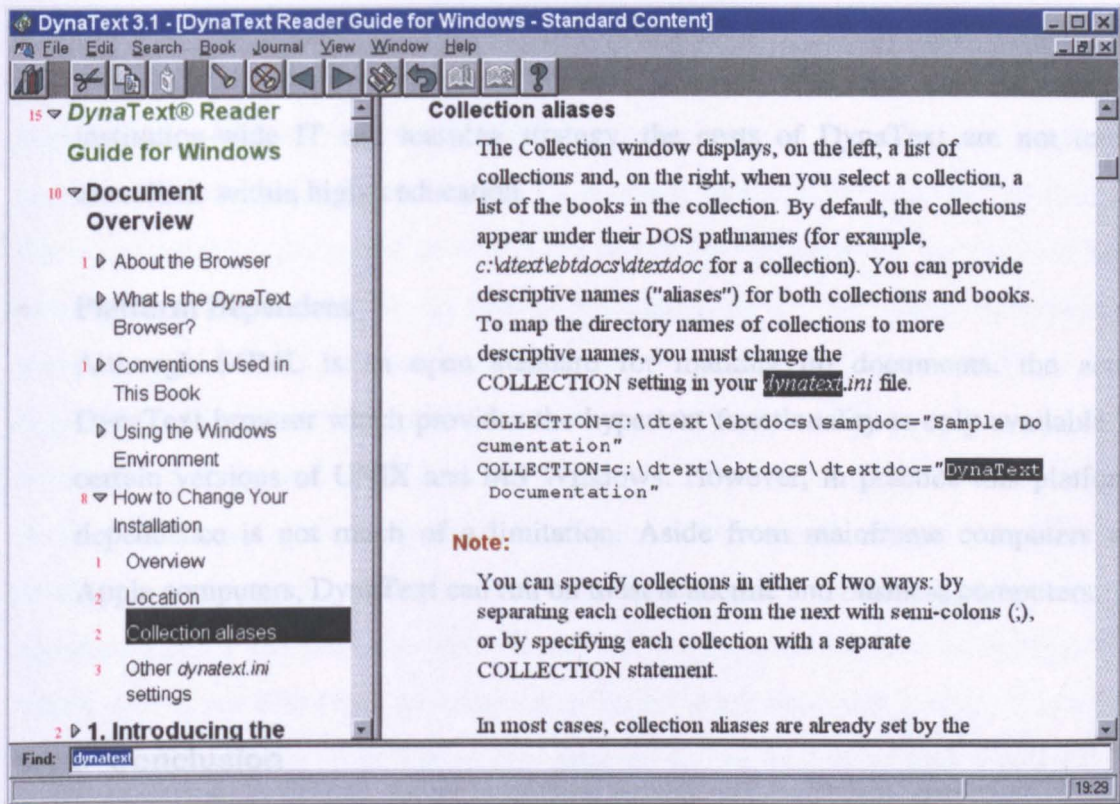
<sup>14</sup> The new HTMLHelp does now support footprints.

being displayed is always highlighted in the table of contents. The current section in Figure 6.4 is 'Collection aliases'. As the user scrolls in the main content pane, the highlighted section in the table of contents will automatically remain synchronised. The latest version of Acrobat reader also has such functionality. However, web sites employing similar frame-based navigational aids do not have automatic synchronisation. And thirdly, the table of contents, after a search has been initiated, will display the number of hits for each section and sub-section. As Figure 6.4 shows, there are 15 occurrences of the keyword 'DynaText' in the section 'DynaText Reader Guide for Windows'. Because the table of contents is a strict hierarchical structure, the user can tell that 10 of these 15 hits occurred within 'Document Overview', one out of the 10 within 'About the Browser' and so on. After a search has been initiated the table of contents can also be 'compressed by TOC hits' to display only those sections which contain the search keyword. 'Sort by TOC hits' is a complementary facility which will reorder the table of contents to display sections in ascending order of hit frequency.

- **Search Highlighting**

In addition to search hits being displayed in the table of contents, each occurrence of the search term(s) is highlighted in reverse video in the main content pane. Such highlighting facilitates rapid visual scanning of the page instead of speed reading whole paragraphs. Unusually for a hypertext system, the DynaText reader displays the search textbox at the bottom of the screen permanently. All the user need to do is click in the textbox to set its focus, enter a keyword or words and hit return.





**Figure 6.4** The DynaText reader just after a search has been executed. The three paned interface shows the number of occurrences of the search term in the table of contents on the left, the terms highlighted in context on the right, and the entered search terms in the textbox at the bottom.

### Disadvantages

- **Cost**

Although DynaText is a powerful hypertext system which appears to exhibit a high level of usability, its biggest disadvantage is its cost. To generate DynaBooks (DynaText hypertext documents), the raw text must be formatted in SGML and then compiled. Whereas there are many HTML editors available, several at low cost, SGML editors are much rarer. A plugin for MS Word is available from Microsoft but it costs several times *more* than Word itself. After the source SGML has been prepared, the DynaText development environment (compiler, browser, etc.) costs roughly £34,000. Licences must also be purchased for each reader at a cost of £400 for 100 users (Inso, *personal communication*). Such high prices make its adoption by single academic departments unlikely. However, with many universities

restructuring traditional computer service units and library departments into consolidated ‘learning resource centres’ charged with the goal of steering institution-wide IT and learning strategy, the costs of DynaText are not totally unrealistic within higher education.

• **Platform Dependent**

Although SGML is an open standard for marking up documents, the actual DynaText browser which provides the hypertext functionality is only available for certain versions of UNIX and MS Windows. However, in practice this platform-dependence is not much of a limitation. Aside from mainframe computers and Apple computers, DynaText can run on most academic and business computers.

**6.1.6 Conclusion**

Of the five hypertext development environments reviewed above, none was found to be superior in every respect. Table 6.1 below summarises the main findings.

**Table 6.1** Key features, speed, platform support and cost of the main hypertext systems considered for this research.

	HyperCard	Adobe Acrobat	HTML	WinHelp	DynaText
Format	Pages	Pages	Scrolling	Scrolling	Scrolling
Contents	No	Yes	No	Yes	Yes
Index	No	No	No	Yes	No
Search	No	Yes	Limited	Yes	Yes
Thumbnails	In history list	Yes	No	No	No
Multi-Window	Yes	No	Yes	Yes	Yes
Speed	Fast	Fast	Slow	Fast	Fast
Platforms	Mac	PC, Mac, Unix	All	PC	PC and Unix
Cost	\$99	£175	Free	Free with MS Windows	£34,000+

HyperCard was rejected primarily on two counts: 1) it is relatively time-consuming to develop large hypertext systems because it is so user-interface intensive, and 2) it only runs on Apple Macintosh computers which represent a small minority of the computers currently used in higher education. Adobe Acrobat, although designed as an electronic document support system and so thus could accurately represent any paper-based book, was rejected on the grounds that it does not easily produce documents optimised for computer screens. HTML was rejected simply on two issues: 1) when the research began the HTML format was still poor in its support for fonts and complex page design work, and 2) even on a local PC and browser, HTML is inherently slower than many standard desktop hypertext systems. Given that modern books can be consulted and manipulated with great speed, the slow operational speed of HTML would be an unfair disadvantage for the computer user. DynaText was rejected because of its high cost, which would possibly limit its adoption in higher education, and its use of specialist SGML markup source code. The system selected for the evaluation was WinHelp. It is pre-installed on all Windows 95/NT machines (free), it is fast and it supports a dynamic table of contents, index and full-text searching. The source code needed to create help files is also relatively easy to generate by using MS Word and saving in RTF format. A description of the implementation associated with WinHelp will be covered in the next section.

## 6.2 Implementation issues

As the review of basic hypertext functionality in Section 4.4 and the description of some of the more common commercial systems discussed in the previous section show, there are a wide variety of different ways to present hypertextual information. Even within a single hypertext system there is also scope to vary the design of a hyperdocument. In fact, as Wright (1989) highlights, hypertext systems can be as diverse as traditional print sources – features which work well in some situations may be inappropriate for others. Thus, not only is it important to evaluate the effectiveness and usability of the final hypertext *product*, it is also vital to document the development *process* which leads to



the final artefact. In other fields, different processes are used in different circumstances to produce similar products. For example, Desktop Publishing software is often used to format posters and brochures, but books are formatted using document processors. The end result to the user is similar, typeset print, but the utility/time trade-off determines when each type of application is appropriate. The same is likely to be true in the case of hypertext. There will not be one perfect authoring system, it will depend on the size of the intended hyperdocument, the technical skills of the authors involved and the development time available.

The following five sub-sections document the specific process of converting *Human-Computer Interaction* by Preece *et al.* from paper-based book format into electronic hypertext format. The process itself reflects Gall and Hannafin's (1994) framework (see Section 4.4) for hypertext functionality. Section 6.2.1 begins by discussing how the raw textual and graphical information was obtained which, in its entirety, represents the 'Knowledge Base'. This information mass was then chunked into nodes (Section 6.2.2) and then a network of hypertext links was inserted to facilitate navigation (Section 6.2.3). Even though the user interface provided by Windows Help is somewhat more restrictive, in terms of its programmability than other hypertext systems, Section 6.2.4 highlights some of the important decisions which do still have to be made. Finally, the chapter closes with a discussion of the compilation process and its implications for testing and debugging.

### 6.2.1 Digitisation

As was stated in Section 6.2 the field of Human-Computer Interaction was chosen as the domain for this research because of its relevance to higher-education students studying Computing and because of the inherent complexity arising from its multidisciplinary heritage. However, as with many domains, the field of Human-Computer Interaction can be presented from several conceptual perspectives. For example, one author might structure a book primarily from a computer science perspective, while another might present similar information from a more psychological perspective. Even within one

particular perspective, there is a wide range of writing possibilities: different writing styles and choice of media (text, photographs, diagrams, etc.). Given such possibilities, before describing the actual hypertext construction process, it is first necessary to cover the decisions made in the selection of the text. Furuta, Plaisant and Shneiderman (1989) stress that hypertext designers should be cautious when identifying suitable sources. As a rough guide they list three heuristics which can be applied in such identification of a good source for hypertextualisation:

1. There is a large body of information organised into numerous fragments
2. The fragments relate to each other
3. The user needs only a small fraction at any time

*Human-Computer Interaction* by Preece *et al* (1994) is a recommended course textbook for the postgraduate HCI module at Napier University. This module is studied by approximately 100 conversion MSc students each academic session. The author undertook his research as a member of the HCI Research Group at Napier University. The choice of text was therefore very relevant to the work of the School of Computing in which the study was done. Evaluating use of a recommended textbook was considered the best way in which to motivate students to take part in the research and to ensure that the research findings were applicable to real-world situations. This particular book was also selected because of the following factors:

- **Size**

At 775 pages in length *Human-Computer Interaction* (hardback) undoubtedly represents a large body of information as recommended by the first of Furuta, Plaisant and Shneiderman's (1989) rules. Past research has found evidence suggesting user disorientation in quite small hyperdocuments: Gray (1990) with a 68-node hypertext, and McKnight, Dillon and Richardson (1990) with a 40-node hypertext. However, if hypertext is to fully replace paper-based books as an educational medium then it is essential to test it at appropriate scales (Meyrowitz, 1991).

- **Structure**

The book also meets the second part of the Furuta, Plaisant and Shneiderman's rule 'organised into numerous fragments' and the second rule 'fragments relate to each other' well. *Human-Computer Interaction* contains six major sections split into a total of 34 chapters. Each chapter also contains a number of individual sub-sections and various inter-chapter references.

- **Presentation**

*Human-Computer Interaction* also meets the third rule relating to the user only needing a small fraction at any time. Not only does it achieve this by its logical structure, but it also employs many of the latest paper publishing techniques. For example, in addition to standard features such as table of contents, index and references, the book also has a glossary and answers section. In the main body of the text keywords are emboldened, various comments are made (displayed on a grey background), and 'boxes' are used to present relevant case studies and additional information.

- **Electronic source**

In challenge number 13, Meyrowitz (1991, p. 315) states, "Publishers should make available, for the next 2 years, machine readable copies of their holdings for non-commercial research in hypermedia by qualified institutions." Obtaining an electronic version of *Human-Computer Interaction* from the publishers Addison-Wesley was essential to the research. Without such electronic source material a work of such size could not have been evaluated within the time constraints of the research. Happily, the publishers obliged.

Having selected a specific HCI title to represent the book condition, it was important to plan the hypertext version. Two broad approaches can be taken in such a media comparison:

## **1. Optimise the material in both media**

It could be argued that in order to conduct a meaningful evaluation between two media, the information within each medium should be optimised. For example, in the case of hypertext, this could mean the inclusion of dynamic information formats such as sound, animation and video. However, as discussed in Section 4.2.2, Clark would argue that it is not the differences in the actual media which resulted in any possible learning variation, but instead that this performance was influenced by the differences in methods used.

## **2. ‘Translate’ material from one medium into another**

The second approach to media evaluation is to keep the information as similar as possible so that the above problem of different methods used is minimised. In the case of book and hypertext, the hypertext system would not employ any information formats not available using paper. Some system designers would argue that if they had to design a hypertext system from scratch on a particular subject then they would not structure it like a book; instead they would take advantage of the unique advantages inherent in the electronic medium. While this is undoubtedly going to be the dominant approach in the future, currently the field of hypertext is still analysing its inherent advantages and many publishers and educationalists are seeking efficient ways of repositioning large quantities of paper-based materials into online systems without extensive rewriting. This is the approach taken here.

Translating book source text into a suitable format to create a hypertext system can be achieved manually, automatically or by a combination of the two techniques. One of the most important processes in converting a document is the identification of its logical structure (Furuta, Plaisant and Shneiderman, 1989). However, since the source text of *Human-Computer Interaction*, as received from Addison-Wesley, did not contain any markup of the logical structure, the decision to use manual translation was taken. The resulting time taken by one person (the author) was two months. This conversion should be considered part-time since other research activities were conducted simultaneously. It would appear that this conversion compares favourably with the manual conversion

described by (Furuta, Plaisant and Shneiderman, 1989) which involved eight *Communications of the ACM* papers translated by two people over six weeks into the Hyperties hypertext system. A large part of converting *Human-Computer Interaction* was in fact taken up by the digitisation of figures and photographs not provided by the publishers<sup>15</sup>. All photographs and detailed figures were converted using a flatbed scanner and a paper version of the book. Due to difficulties in precisely aligning pages on the scanner, simple figures such as diagrams were redrawn in Paint Shop Pro paint package. A second initial stage that could also be eliminated in the future was the need to reformat the text. This was accomplished by visually scanning the paper book by eye for any headings and titles, italicised or emboldened words and then manually altering the corresponding word in the electronic version using MS Word. Because of the length of *Human-Computer Interaction*, the electronic format was stored in a number of Word documents. Conveniently, the book itself is split up into six main parts that were of manageable size in Word.

## 6.2.2 Node Creation

Following text and graphics formatting, the next main decision to be made concerned node granularity – how to divide the book into individual hypertext nodes. As Balasubramanian (1994) warns, if the size of nodes is too small then there is the risk of fragmentation of ideas and arguments, but conversely, too large and various design problems occur in how to display all the information. Britt, Rouet and Perfetti (1996, p. 46) also warn, “Converting linear text into hypertext may decrease comprehensibility of the materials, especially because coherence breaks down at the local and global levels.” Alschuler (1989) presents a review of three different hypertext implementations of the July 1988 issue of *Communications of the ACM*, which reprinted six papers from the Hypertext '87 conference. Although each of the three systems represented exactly the same papers, their node formats differed radically. For instance, the HyperCard implementation ignored the original paper structures and instead formatted the information into a number of screens, KMS on the other hand preserved each paper's

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<sup>15</sup> Only text was supplied in electronic format.

logical divisions by using scrollable nodes of differing lengths, and Hyperties used a combination of both approaches – each paper’s logical structure was maintained, but at the same time broken down into screen divisions suitable for display. Alschuler reports that the disadvantage of the HyperCard screen-based presentation was that sometimes bulleted lists would span more than one screen but no interface cues were provided in such circumstances. She states that readers must navigate in a linear fashion to determine whether the current idea continues on subsequent screens or not. Since WinHelp automatically provides scrollable nodes where there is more text than can be viewed on the screen, it seemed sensible to adopt the KMS approach and split *Human-Computer Interaction* along its logical boundaries. This was accomplished by placing each section (about four or five pages in length) into individual nodes. This maintains the coherence of the authors’ arguments while at the same time does not require excessive scrolling within each node. This conversion resulted in approximately 254 ‘main’ nodes. The ‘Key Points’ and ‘Further Reading’ sections for each chapter were converted into two separate nodes as well. As stated in the previous section, it was considered potentially useful to display glossary terms and references in small pop-up nodes. This would hopefully reduce cognitive load and remove the necessity to use the backtracking button in these circumstances. However, each glossary item and reference had to be converted into an individual node, one per pop-up. This increased the total size of the hypertext system from the 254 main nodes up to 1,634.

### 6.2.3 Link Insertion

With the document split up into its constituent nodes, hypertext links could be inserted. A brief review of the hypertext literature yielded a potential minefield of inappropriate design possibilities. For example, Alschuler (1989) reviewing the HyperCard, KMS and Hyperties implementation of the Hypertext ’87 papers mentions the differences in linking structures used.

“The different link structure does not appear to be the result of design decisions, but of the subjective nature of this type of hypertext. The lack of relationship between different linking schemes, even within the same program, the random

order of embedded links and their erratic coverage of the subject matter are hallmarks of hand-crafted hypertext links."

*Alschuler (1989, p. 358)*

Although Alschuler appears to blame the above problems on manually inserted links, which may be partially true, part of the problem of hypertext structuring concerns the idiosyncratic nature of the authors' mental models. As Lowe and Hall (1999) highlight, a group of subject matter experts can generate quite different link sets for a given domain. To avoid these problems, it was decided that the hypertext version of *Human-Computer Interaction* would mimic, as closely as possible, the structure employed by the paper-based book. Where changes in structure did have to be made, these alterations are discussed below. Although WinHelp only supports two link types, and these are only really concerned with window display properties, the following discussion will describe the link insertion process from three perspectives: associative links, structural links and referential links.

### ***Associative Links***

As discussed in Section 4.4, there is wide variation in functionality among the various systems which may be included under the umbrella term 'hypertext'. However, one factor common to them all is their ability to support associative links. First proposed by Bush in 1945, these are machine-supported connections between related pieces of information. These links are necessary because the human brain both consciously and sub-consciously searches for meaningful associations between various concepts. Although the pages of traditional based books are bound in linear sequence, writers have evolved various literary equivalents of the associative link. Two main types exist which again have evolved because of the physical construction of paper-based books. The first example, when referring short distances, is to use terms such as "see above" or "see below". However, if an associated topic is a number of pages away from the current location these terms become vague and of not much use to the reader. Thus, for longer jumps, phrases such as "as discussed in Chapter 2" are used. Sometimes actual page numbers are included too.

Although hypertext can support any number of machine-supported associative links, Lynch and Horton (1997) warn:

“Associative links entail two fundamental design problems: They disrupt the narrative flow by inviting the reader to go somewhere else, and they can radically alter the context by dumping the reader into unfamiliar territory with insufficient explanation.”

(Lynch and Horton, 1997, p. 115)

In an attempt to limit this problem of disruption, local intra-page links such as “see below” found within *Human-Computer Interaction* were kept as text-only linguistic pointers. Although active hyperlinks could have been constructed to jump down the current node, this could have had two negative effects. Firstly, too many links, illustrated in a different colours, could be visually distracting when trying to read through a carefully written linear argument. And secondly, since the majority of links within the converted book would lead to different nodes, having links within a node could cause navigational confusion in some readers. For example, a user might click on a link and think that the destination is a new node whereas it is simply further down the same node.

Although the inclusion of intra-page links was rejected because of the above reasons, links between pages were included. Links between various pages were typically inter-chapter references such as “see Chapter 10” for example. The overall number of such links was small enough not to pose a serious problem disrupting the reading process, but at the same time made good use of hypertext’s ability to rapidly traverse different parts of the hyperspace. To avoid the problem outlined by Lynch and Horton (1997) of ‘dumping the user into unfamiliar territory’ the link labels were amended to provide the user with more information regarding the destination of the link. Thus, rather than the user having to execute a link to determine whether it jumped to the required information, additional information was provided at the link anchor to describe its destination. Thus, the numeric chapter references of the book were converted into textual chapter titles. For example, “see Chapter 10” would be replaced in the hypertext



version with a link reading “see Organizational Aspects”. A second reason for choosing textual links over numerical versions concerned more fundamental aspects of the hypertext paradigm. Norman (1994) and Balasubramanian (1994) claim that links encourage associative learning by processes of exploration and discovery. It is important to realise that what these authors are describing is conceptual exploration, not physical exploration. If the hypertext version of *Human-Computer Interaction* utilised the numerical chapter references as the book version, knowledge of these numbers could artificially constrain users exploration. For example, if a link refers to Chapter 6 but the user has not read Chapter 5 then they may be unwilling to traverse the link. Utilising chapter titles for link labels enables a purely conceptual hyperspace topology instead of the paper-based system of associative linking superimposed on a physical linear topology.

### ***Structural Links***

Although, as mentioned above, many proponents of hypertext are keen to stress the benefits of associative links, research by Mohageg (1992) suggests that these network structures alone are insufficient. He found that that for hierarchical-type tasks the network structure resulted in completion times significantly longer than the hierarchical structures or combination structures (network and hierarchical structures used together). Thus, Mohageg concludes, “hierarchical linking structures should be implemented for most hypertext (or text-intensive) data bases used for information retrieval.” (p. 366). A second reason why hierarchical link structures are important in hypertext is because text comprehension requires sophisticated cognitive strategies. As Rouet and Levonen (1996) argue, subjects have little experience of reading nonlinear materials, their skills are closely dependent on familiar book text structures. To take advantage of these already developed skills and strategies it makes sense to replicate these structures within hypertext, certainly until the nonlinear skills are developed. Finally, a third motivation for the inclusion of a hierarchical link structure can be found in the cognitive style literature. For example, Witkin, Moore, Goodenough and Cox (1977) found that individuals with a field-dependent style have difficulty imposing structure on material which is presented in an unstructured format. However, they argue that if the material is

already organised and thus does not require restructuring then the performance of field-dependent and field-independent individuals is not likely to differ. As a result of these factors, the hierarchical structure used in the paper version of *Human-Computer Interaction* was copied into the hypertext version. The hierarchical structure of the book can be seen in two places in the hypertext: the table of contents near the beginning, and in the short chapter contents lists at the beginning of each chapter.

The main table of contents was converted into WinHelp's dynamic contents window. Initially, the contents appear with just the top-level sections listed. To reveal the sub-sections within any of these primary sections the user can double-click with the mouse. As Figure 6.5 shows, there are two table of content objects: parent nodes symbolised by book icons and child nodes represented by individual page icons with question marks. The book icon has two visual states to indicate whether a particular hierarchical branch has been expanded (open book) or contracted (closed book).

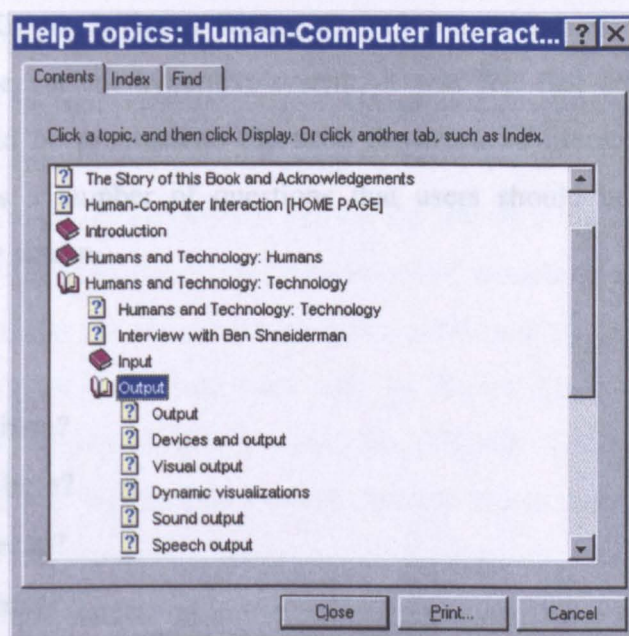


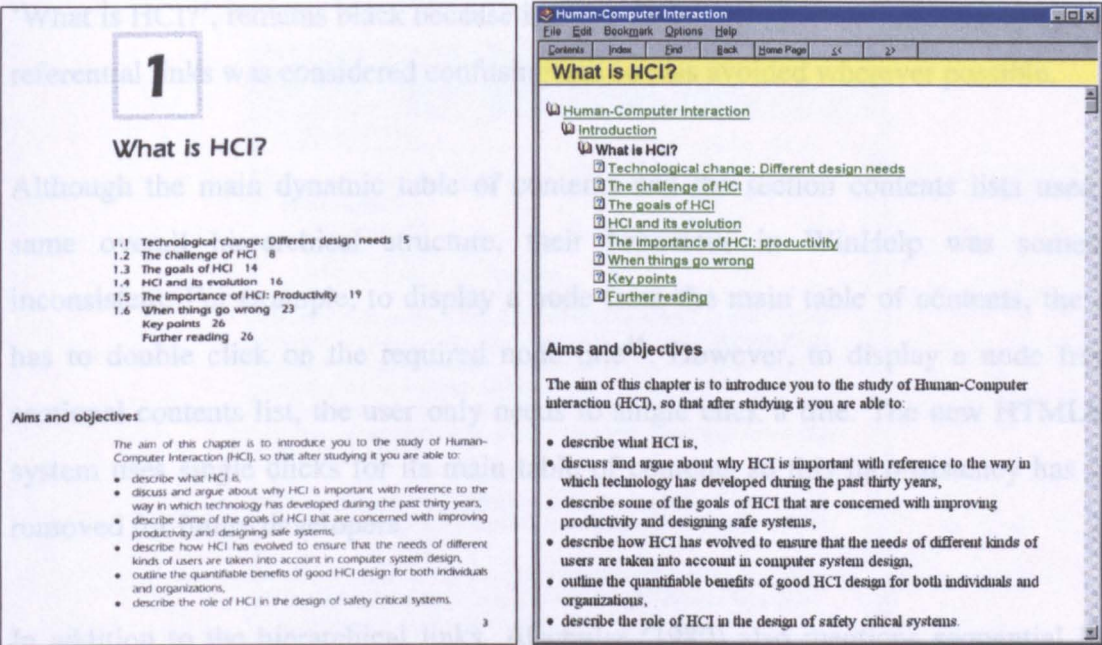
Figure 6.5 The branching table of contents provided by WinHelp.

One small alteration, that did have to be made in the conversion between *Human-Computer Interaction* and WinHelp, was that in the hypertext, the parent items in the table of contents could not link directly to any nodes, they could only contain children. Thus, the first child within each parent (chapter in the book) has the same name and this links to the relevant node. This can be seen in Figure 6.5 above – the first child link under the ‘Output’ chapter is also called ‘Output’. However, it is important to stress that this is a specific limitation of WinHelp and does not necessarily apply to other hypertext systems. Indeed the problem could also be solved, assuming prior knowledge of this WinHelp limitation, by writing material specifically formatted to obviate this duplication.

In addition to the standard table of contents, each chapter within *Human-Computer Interaction* also listed its sections. An example of the Chapter 1 sections can be seen in Figure 6.6a. Initially these section headings were simply transferred into the hypertext version and made into clickable links. However, as stated earlier, several studies have discovered user disorientation problems when navigating virtual information spaces (Gray, 1990; McKnight, Dillon & Richardson, 1990 and Nielsen, 1990). To avoid such problems with the current hypertext system, it was felt that additional navigational information should be provided to the user. A review of literature on the subject of navigation reveals a number of questions that users should be able to answer for themselves on any screen.

- Where Am I?
- How did I get here?
- What can I do here?
- Where can I get to?
- How do I go there?
- What have I seen so far?
- Where else is there for me to see?





**a.** **b.**

**Figure 6.6** a) The list of sections within Chapter 1 of the book version, b) The clickable list of sections, including parents, within Chapter 1 of the hypertext version.

Hypertext system proposals from Benest (1991) and Catenazzi and Sommaruga (1994) attempt to answer the above questions by graphically emulating the tactile information provided by an open book. For example, both proposals utilised a two page design symbolising an open book and used shading to indicate the user’s position within the book. However, Nielsen (1990) argues against the use of book oriented metaphors in hypertext design because they can limit the conceptual models of users – they might not know about the ability to search or navigate non-linearly. Also, from a practical perspective, developing the visual cues used by Benest (1991) and Catenazzi and Sommaruga (1994) within WinHelp would be difficult. The final solution to the navigation problem was to extend the chapter contents lists to show parent nodes as well as the child nodes. For example, a parent node ‘Introduction’ was added to the current node (‘What is HCI?’), and its parent node ‘Human-Computer Interaction’ (root node) was also added (see Figure 6.6b). Clicking on this top-most link entitled ‘Human-Computer Interaction’ has the same effect as selecting the ‘Home’ button from the WinHelp toolbar. Also, it should be highlighted that the current node itself, in this case

'What is HCI?', remains black because it is not an active hypertext link. The use of self-referential links was considered confusing and so was avoided wherever possible.

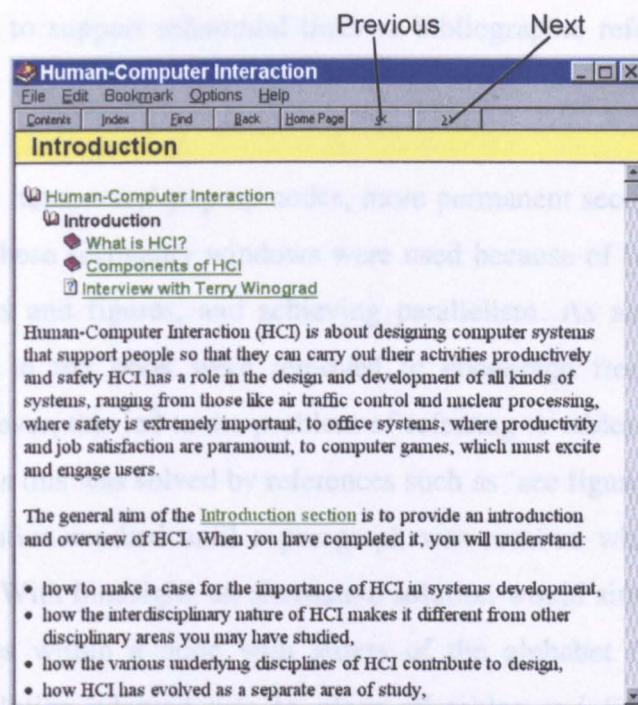
Although the main dynamic table of contents and the section contents lists used the same overall hierarchical structure, their behaviour in WinHelp was somewhat inconsistent. For example, to display a node from the main table of contents, the user has to double click on the required node title<sup>16</sup>. However, to display a node from a sectional contents list, the user only needs to single click a title. The new HTMLHelp system uses single clicks for its main table of contents so this inconsistency has been removed for future developers.

In addition to the hierarchical links, Alschuler (1989) also mentions sequential links. These are links that connect nodes in the order in which they would appear in print. Again, WinHelp's automatic support for sequential links was one of the factors considered when choosing the system. Buttons for navigating to previous and next nodes in the hyperdocument can be seen in the button toolbar shown in Figure 6.7. Nodes to be included in the sequence can be added by creating a '+' footnote within Word. The exact sequence is later rendered at compilation time in the Help Compiler Workshop.

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<sup>16</sup> Or single click the title and then select the 'display' button.





**Figure 6.7** WinHelp main window with previous and next buttons on the toolbar.

### **Referential Links**

In addition to the main associative links used to 'join' related concepts and the structural links which support hierarchical and linear link structures, referential links form a useful third conceptual link type. These are described by Lowe and Hall (1999) as similar to associative links, but link from one piece of information to an elaboration or explanation of that information. Using this definition, it appeared that glossary definitions and bibliographic references were referential in nature. Although WinHelp does not explicitly support a referential link type, it does support pop-up nodes through a special link type. Studies have shown that users are willing to lookup unfamiliar terms using popup nodes (Black, Wright, Black & Norman, 1992), and that they rate popup nodes as less cognitively demanding than replacement nodes for certain types of information (Stark, 1990). Interestingly Stark found that users assigned to a popup node group commented more about the organisation of the information than about the actual user interface compared with users in a replacement node group. In the current study popup

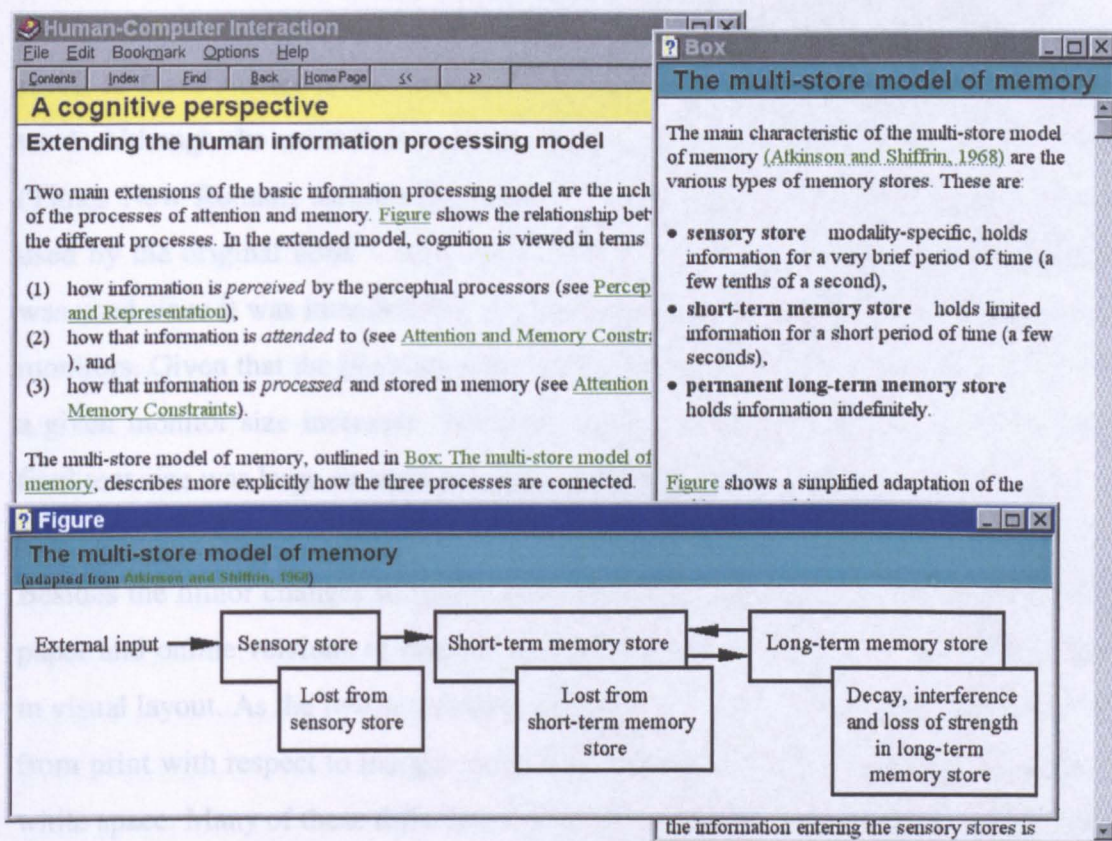
nodes were used to support referential links to bibliographic references and glossary definitions.

In addition to the 'temporary' pop-up nodes, more permanent secondary windows were also employed. These secondary windows were used because of two main advantages: referring to tables and figures, and achieving parallelism. As already mentioned, all section numbers in the book were removed to encourage free exploration of the hyperspace. However, this led to the problem of referring to tables and figures. Initially in early prototypes this was solved by references such as 'see figure below' or 'see table above'. This solution worked until a paragraph was reached which referred to three different figures. With hindsight, an alternative solution would simply be to identify all tables and figures within a node with letters of the alphabet or Roman numerals. However, the solution adopted was to place all tables and figures inside separate windows (referred to in WinHelp as secondary windows). When the user clicks on the 'Table' or 'Figure' link a new window appears containing the required information. This new window can be resized, re-positioned, minimised, maximised and all the other manipulations which Windows 95/NT permits. The second advantage of using a separate secondary window is that it achieves a limited form of parallelism. Min (1994) observed that parallelism is a phenomenon which occurs frequently in everyday life and indeed is an essential component of good learning environments. A good example of parallelism which most people are accustomed to is driving a car. A good driver will assess the placement of his or her car on the road and refine its position as necessary through steering, check mirrors, read road signs and monitor the car's speed using the speedometer. Although it could be argued that attention is only focused on one activity at any given moment in time, it is the ease and frequency of attention-switching which achieves the effect of parallelism. This is much like a multitasking operating system switching between applications so fast that it appears to users that all processes are running at the same time. Returning to the hypertext system used in the current research, it is possible for a user to read the text in the main window and then almost effortlessly switch attention to a figure or diagram in a secondary window (see Figure 6.8). Although tables and figures are usually inserted near the relevant section of text in a

printed book, there are occasions when figures and tables have to be printed overleaf. In such circumstances there is a pronounced interruption in attention as the reader switches into a search mode to look for the additional information.

However, the use of secondary windows to display tables and figures does have disadvantages. For example, the user *must* click on a link to see a table or figure, whereas in a book most users cannot help but see tables and figures while they are visually scanning a page. A second disadvantage is that users are burdened with additional window management responsibilities. If the windows are large and the screen resolution is low, it is likely that various windows will need to overlap thus hiding parts of the information. Also, one of the limitations of WinHelp is that secondary windows are named. Unlike HTML that can open up an unlimited number of browser instances, the WinHelp source code specifies a precise window name or ID. If a named window is already displayed when it is required for a second time then the new content will replace the old in the same window instance. Each distinct use of secondary windows, for example 'figure', 'table', 'box' and 'answer', uses its own specific name so that it is possible to display any combination of these simultaneously but not multiple instances of the same type (e.g. 'figure'). The primary and secondary windows used by WinHelp (excluding pop-up windows) use standard Windows 95/NT window controls. To close a secondary window the user selects the standard cross icon in the top right corner. However, it can be easy to click too many times and accidentally close the main window, resulting in fully exiting the hypertext system. No warning dialog boxes are displayed when exiting the system. In an attempt to minimise unintentional exits, the non-scrollable region of the primary window was coloured pale yellow while the non-scrollable region of all secondary windows was coloured cyan as a visual cue.





**Figure 6.8** Multiple windows: main window with pull-down menu and button bar, and two secondary windows displaying a box and a figure.

### 6.3.4 User Interface Considerations

Having chunked the book into a number of nodes and inserted links between these nodes, attention was given to optimising the user interface and the overall presentation of the information. One of the most obvious aspects of the user interface of a book or a hypertext system is the colour scheme and typefaces used. As already mentioned in Section 4.5.4, Gould *et al.* (1987b) found online and paper reading speeds similar when a number of factors common to the two media were held constant. For example, reading from CRT displays was found to be faster when using dark text on a light coloured background, proportional spaced fonts and a high display resolution. Tullis, Boynton and Hersh (1995) also found when testing screen reading that reading speed was significantly faster, better accuracy in finding typographical errors was observed and

more favourable subjective ratings by users were obtained when using larger fonts. As a result of these studies it was decided that black text on a white background should be used. Although the exact font typefaces differed from the printed book, both body text (Times New Roman) and headings (Arial) were from the same font families as those used by the original book – serif and sans-serif respectively. Fourteen point body text was used since it was intended that the hypertext should be displayed on high resolution monitors. Given that the physical size of text and graphics decreases as the resolution of a given monitor size increases, this large body text found was used to ensure that the final text size was large enough to ensure comfortable online reading.

Besides the minor changes in typefaces used, a more noticeable difference between the paper and online versions of *Human-Computer Interaction* was the inevitable disparity in visual layout. As the two screenshots in Figure 6.6 show, the hypertext version differs from print with respect to margin sizes, line leading, indentation and general amount of white space. Many of these differences were caused by the limited typographical options available within WinHelp. The layout could have been preserved using Adobe Acrobat, however the use of this particular system was rejected on the basis of other issues as discussed earlier. Although WinHelp has simplistic typographical control, one of its strengths is the non-scrollable region available in all main nodes (excludes pop-up nodes). As mentioned earlier, because hypertext systems do not replicate the many tactile cues afforded by paper books users can become disorientated. To address this problem the title of the current node was displayed within this non-scrollable region. In Figure 6.6b the non-scrollable region can be seen as a light yellow strip under the toolbar containing the node title ‘What is HCI?’. The advantage of placing the title within this region is that even when the user scrolls down the current node the title always remains visible.

6.3.5 Compilation

After saving the help file source as rich text format (RTF) the Help Compiler Workshop (HCW) was used to compile this into a finished help file. One of the unexpected benefits that the HCW provides was found to be automatic link checking. That is, the compiler checks that the node ID that a link points to actually exists. Although the HCW can be fooled, like a spell-checker, into thinking that a wrong link (from the author's point of view) pointing to a legitimate node is correct, in reality it is much more common for mis-typed node names or link addresses to be the source of problems. Currently, link accuracy on the Internet is a large problem. Although this is due to authors moving and deleting nodes and not informing other sites with pointers to the information (which would be impractical), small insular sites with internal links must check them to make sure the links work. With the HCW, much of this work is handled automatically. As Figure 6.9 shows, the HCW displays a list of all links that attempt to jump to nodes that do not exist.

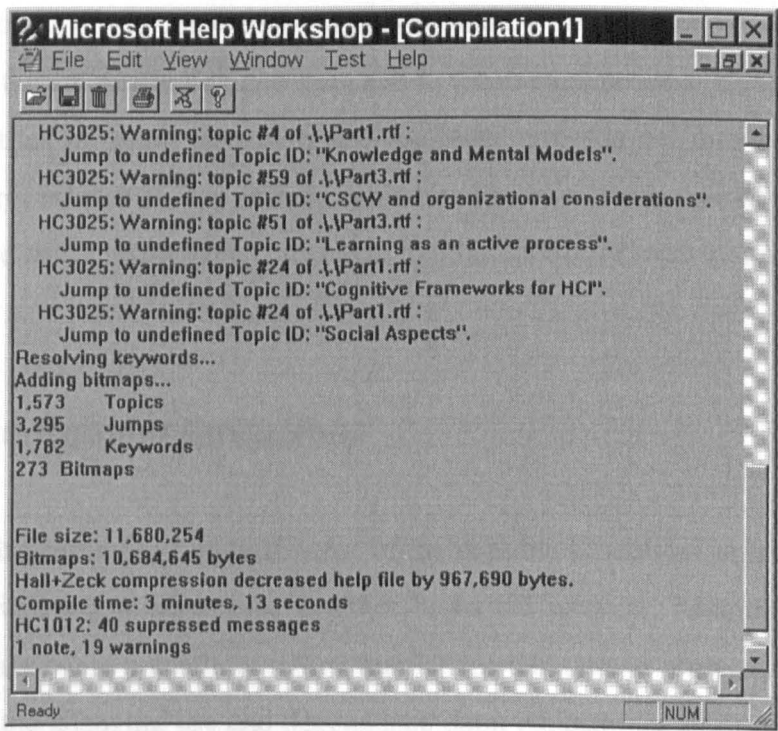


Figure 6.9 Warning messages and summary produced by the Help Compiler Workshop.

An unexpected bonus from the automatic link checking of the HCW was the detection of a number of errors made in the published *Human-Computer Interaction* text. Twenty-five references in the text could not be found in the references section. A further two references appeared to be misspelled: Text - Ehn and Sjögren, References section - Ehn and Sögren, and Text - Moll and Sauder, References section - Moll and Sauter. Other problems detected manually included: two different Table 5.1s (page 110 and 113), 'distributed cognition' listed after 'distributed representations' in the index, and over 36 page number mistakes listed in the index. These numbering mistakes were confined to the bottom of glossary pages. For example, 'decomposition' is listed in the Index as being on page 711, however it is actually at the top of page 712. In practice, with the glossary listed alphabetically, this type of error is not serious. However, this and the other problems mentioned provide interesting information about the prevalence of various types of errors. Most readers, just looking up the occasional references or dipping into the index, would probably imagine that books do not have many 'bugs' in them. The success of the conversion process in finding these errors can be attributed to the HCW for the automatic link checking and to the manual process of converting tables and index entries by hand. Detection of these latter errors is not due to the hypertext conversion process *per se*, but instead probably due to a 'fresh pair of eyes'. Similar benefits would likely result from conversion to other media, or even into another book.

## 6.4 Design transfer limitations

At this point it is useful to highlight some of the possible limitations regarding applying the above development experience to other hypertext projects. Although the specific design decisions could potentially inform similar sized hypertext projects, it is important to appreciate the changing use and dependence upon educational technologies. Early in the development of computer-support education, individual CAL packages were used as occasional adjuncts to traditionally taught courses. Examples of this include the various



educational packages available for the BBC range of computers used in schools in the 1980's. Such packages, although educationally effective in some cases, were probably used more to motivate students rather than to boost academic performance. The following phase of educational hypertext use involves structuring an entire course/module around online material. A wide variety of such course-based systems are available on the Internet. However, across a degree programme the students may experience some traditionally taught modules and some computer-based modules. Depending upon the precise level of integration between the various modules this system may or may not work sufficiently. Beyond individual online courses lies the development of computer-based degrees. In such cases, for example the current TLTP3-86 project to develop medical online systems (NLE, 2000), instead of hypertext being a useful adjunct it becomes the central focus with which to store, manage and manipulate an entire curriculum. At this stage, hundreds of staff across a faculty may be involved in making this type of development qualitatively as well as quantitatively different from the hypertext development reported in this thesis. One of the important factors not experienced in the current hypertext translation was the socio-organizational problems encountered when dealing with many academic contributors. Whereas on a small conversion a single skilled individual can handle all aspects of the development, larger projects require specialist personnel in instructional design, programming, HCI design and computer graphics (Ellis, 1997). As Ellis states, "This is a very different scenario from the individual instructor deciding what to teach, how to teach it, and simply going ahead and doing it alone." (Ellis, 1997, p. 260). As well as more complex development and technical issues, various social issues can surface. For example, it is the experience of the current author on the faculty-wide Networked Learning Environment and Herson, Sosabowski and Lloyd (1999) that barriers to successful adoption of online systems can be due to staff worries over confidentiality of material (especially on open-systems such as the Internet), increased peer scrutiny and the possible increase in workload caused by the new systems.

## 7. Experiment 1 – Individual Differences

### 7.1 Introduction

Utilising the paper version of *Human-Computer Interaction*, together with the hypertextualised version described in Chapter 6, the current chapter describes a set of empirical experiments designed to test the hypotheses set out in Section 5.2.

As discussed earlier (see Section 2.3.3), there have been numerous studies investigating the effects of both matching and mismatching specific individual differences with various educational treatments and methods. While such research has undoubtedly been very important, its greatest contribution has been to the field of educational psychology, not to general educational practice. While any good teacher or lecturer will monitor and adapt to student differences when explaining concepts, this accommodation does not usually extend into pre-created media. Often there is insufficient time to create multiple copies of a tutorial, for example, and the likelihood of the subject matter changing significantly in the near future reduces even further the desire to develop more than one version. However, the accommodation of student differences is still important if none are to be disadvantaged. If multiple versions of course materials are too expensive to develop, then it would appear that a single edition is the only feasible option. This can either be a single edition which through the use of adaptive technologies monitors and adapts to individual differences (Kay & Kummerfeld, 1997), or it could be a single edition which has been subjected to ‘individual differences’ evaluation in an attempt to detect and remove any problems. It is this second option that the current experiment was designed to support. As already mentioned, there have been many studies which have demonstrated significant correlations between performance and various individual differences, but some appear quite artificial. Many employ ‘gross’ differences between experimental versions, comparing, for example, textual material to graphical material or structured to unstructured. While such manipulations often result in significant performance differences, practising educators do not often consider such widely differing treatments. What is needed is information concerning the ability of individual

differences analysis to inform and contribute to the design of realistic ‘off-the-shelf’ media. As such, the aim of the first experiment was to compare the usability of a hypertext system and a book covering the same multi-disciplinary knowledge domain. As will be discussed in more detail below, a number of individual differences were measured for each subject before they participated in two experimental tasks: basic information retrieval questions and open-ended essay questions.

## 7.2 Methods

### 7.2.1 Subjects

Fifty-seven postgraduate student volunteers from Napier University who had elected to study Human-Computer Interaction took part in the experiment. Thirty nine subjects were male and 19 were female. Their ages ranged from 21 to 57 years with a mean of 28.4 years (SD=6.7).

### 7.2.2 Materials

#### *Cognitive Tests*

Two separate tests were used to assess cognitive style: the Group Embedded Figures Test (GEFT) developed by Witkin *et al.* (1971) which is used extensively in the literature, and a much newer test developed by Riding (1991) called the Cognitive Styles Analysis (CSA). Spatial ability was measured by the Shapes Analysis Test (Heim, Watts & Simmonds, 1972).

The Group Embedded Figures Test (GEFT) measures a cognitive style labelled field-dependence (or ‘field articulation’). At one end of this dimension ‘field-dependent’ individuals can process stimuli as a whole (quickly obtain an overview), while at the other end of the dimension ‘field-independent’ individuals are quicker at processing

selected parts of a stimulus (focusing on details). To test this field-dependence cognitive style, the GEFT requires subjects to trace a set of simple geometric shapes onto a set of 18 complex figures (no rotation required). An example of one of the GEFT questions can be seen in Appendix A, Figure 1. After a two minute practice session, subjects are allowed five minutes to complete the first nine assessed tasks and then a further five minutes for the remaining nine tasks (18 assessed tasks in total). A low score (incorrect tracing or not attempted) indicates a field-dependent style, while a high score indicates a field-independent style. The manual states that the GEFT has a reliability (between first and second sections) of  $r=0.82$  for both males and females.

The second test, Cognitive Styles Analysis (CSA), being a much newer test, has not been subjected to as much rigorous investigation as the GEFT. The advantage of the CSA test is that unlike most 'traditional' cognitive style tests, it measures positively both ends of the style dimension. The GEFT measures positively only field-independence, field-dependence is assumed when a low GEFT score is obtained. The CSA test, as outlined in Section 3.4 above, measures two distinct styles: how information is *processed* 'wholist-analytic', and how information is *represented* 'imager-verbaliser'. To accomplish this, four types of questions are presented (see Figure 2 in Appendix A). The test begins with 48 textual questions assessing imager-verbaliser style. Questions asking whether two objects are of the same type<sup>17</sup> assess verbaliser style, while questions asking whether two objects are the same colour<sup>18</sup> assess imager style. Next 20 screens, each presenting two geometric patterns, are used to assess wholist type. Respondents are asked to indicate for each screen whether the two figures are identical or not. Analytic style is assessed, again using 20 screens, by asking respondents to indicate whether a simple shape is contained within a more complex arrangement of shapes. All questions are answered yes or no indicated by red and blue stickers placed over the full stop and forward slash keys on the keyboard. By presenting the questions using a computer, precise timings can be obtained. Not only that, but in addition, an individual's reaction times on the wholist type questions are compared with

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<sup>17</sup> e.g. GOLF and TEA POT the same TYPE

<sup>18</sup> e.g. LETTUCE and LAWN are the same COLOUR



the same individual's reaction times on the analytic type questions (and the same for imager/verbaliser questions), instead of comparing with group means. This within-subject comparison avoids the disadvantages of variance in the reaction speeds of different individuals. After the test is complete the system outputs one numeric value for the subject's wholist-analytic style, one for their verbaliser-imager style and the percentage of questions answered correctly for each dimension. The percentage accuracy is not actually used to determine style, they are just listed for the benefit of the researcher. Peterson, Deary and Austin (2001) found that the reliability of the wholist-analytic dimension of CSA was  $r=0.689$  but the verbaliser-imager dimension was not reliable at only  $r=0.357$ .

In addition to the two measures of cognitive style, the spatial ability of all subjects was measured using the Shapes Analysis Test (Heim *et al.*, 1972). This test consists of 18 two-dimensional and 18 three-dimensional tasks requiring mental rotation. A three-dimensional area estimation question is reproduced in Figure 3 in Appendix A. After a practice set of questions which does not contribute to the final score, subjects are permitted 25 minutes to complete the test. The test manual states that the questions become increasingly difficult and it is unlikely that subjects will complete all questions. The Shapes Analysis Test manual claims a test-retest reliability of  $r=0.774$  ( $p<0.001$ ). Although the manual admits this is low, it does, however, suggest that one reason for this could be due to the variety of question types used (i.e. estimating area, figure removal, figure combination) and the combination of two-dimensional and three-dimensional questions.

### ***Experimental Media***

Two versions of a major Human-Computer Interaction (HCI) textbook (Preece *et al.*, 1994) were used: book and hypertext. The hardback book was approximately 800 pages in length and had standard book features such as: contents list, index, references and a glossary. The book was chosen for its richness of content, its multi-disciplinary subject matter, highly organised presentation, and physical size. A description of the conversion process from book to hypertext implementation was given in Section 6.4 above. The

hypertext version of the book utilised WinHelp 4.0 and thus was able to run on any IBM compatible computer using Windows 95/98 or Windows NT 4.0. Although the hypertext version of the book was not evaluated in a pilot study prior to the experiments, it was shown to the director of studies and a professor from the department knowledgeable on HCI issues. It was assumed that WinHelp software would have undergone extensive testing at Microsoft and so it would only be the structure and layout of the content information that would be likely to cause a problem. Given, as explained in the previous chapter, that the hypertext system used the same overall structure as the book, and it is difficult obtaining student volunteers, it was decided that proceeding without a trial would be acceptable.

### *Task Materials*

Two sets of tasks were devised to investigate the relative performances of Book and Hypertext users. The first task, 35 closed questions (see Appendix B), was designed to test the ability of each medium to support the locating of factual information using a variety of retrieval mechanisms: table of contents, glossary, reference list, index. Although subjects were free to choose any retrieval mechanism supported by their medium, some questions were designed to be found easier using specific mechanisms. For example, Question 2 (see Appendix B) which asks subjects to list the disciplines which contribute to HCI could easily be found by consulting the table of contents. The word 'disciplines' is not indexed, only 'human-computer interaction (HCI): disciplines contributing to'. In another example, the definition of multimedia (Question 9) could be found using the index, a two step process, or alternatively found directly in the glossary. Task 2 presented four open questions based around a short scenario, reproduced in Appendix C. These required analysis, synthesis and application of information from different parts of the document as well as general information retrieval skills. Whereas the first task elicited purely quantitative data concerning comparative speed of access of the two media, performance on the second task was assessed according to the qualitative merit of each answer.

A follow up questionnaire, listed in Appendix D, was also used to collect attitudinal data. A combination of closed and open-ended questions sought information such as previous computer experience, the perceived advantages and disadvantages of the assigned medium and the usefulness of specific facilities (e.g. table of contents, index, find) provided by the medium.

### 7.2.3 Procedure

The experimental sessions were conducted at the beginning of the semester. Most students at this stage had not read the text book or learnt much HCI. At the first session all subjects were given a 25 minute introduction to the research and the GEFT test administered. One week later, in computer laboratories, all subjects were given the computer-based CSA test and the paper-based Shapes Analysis Test.

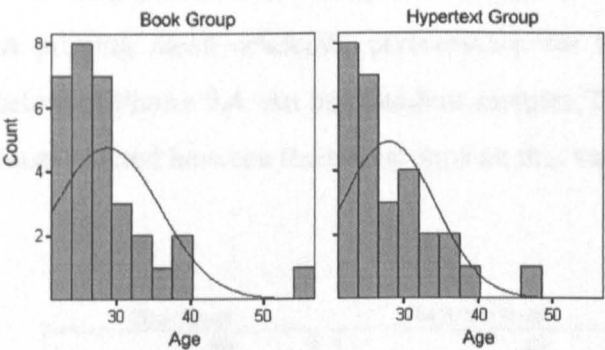
Subjects were allocated to matched book and hypertext conditions by balancing the groups as closely as possible on three factors: mean CSA (WA) score, mean Shapes Analysis Test score and mean age (see Table 7.1). With each additional factor it becomes harder to match groups and still remain balanced on the other factors. As such it was decided not to match the groups on GEFT score and CSA Verbaliser-Imager score. GEFT was rejected since Riding and Cheema (1991) claim that the newer CSA test measures the same field dependent cognitive style. And the VI dimension of CSA was not used since the information retrieval aspects of the task questions were not thought to relate to this particular cognitive style. The two groups were created initially in MS Excel by randomly assigning half the subjects to the Book group and half to the Hypertext group. The means and standard deviations of each group was then compared on the CSA (WA), Shapes Analysis Test and age dimensions. Where large differences between the groups occurred, pairs of individuals from each group were swapped until the mean scores and standard deviations were as close as possible. Independent Samples T-Tests revealed that there were no significant differences on the three variables between Book and Hypertext groups. The resulting pre-experimental means, medians and standard deviations of Book and Hypertext groups on age, CSA (WA) score and

Shapes Analysis test score are shown below in Table 7.1. Once allocated subjects remained in the same group for both experimental tasks.

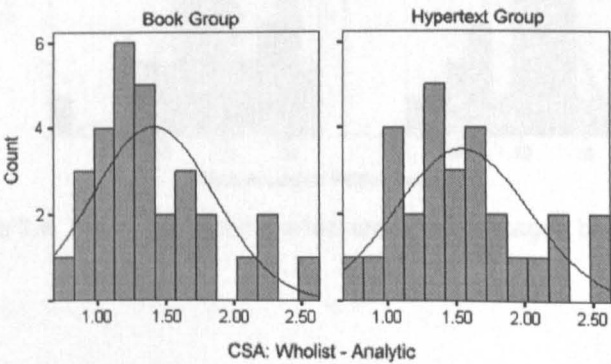
Book Group (n=30)				Hypertext Group (n=27)			
	Age	CSA (WA)	Shapes Analysis		Age	CSA (WA)	Shapes Analysis
Mean	28.7	1.50	15.58	Mean	28.1	1.52	15.24
Median	28.0	1.39	17.00	Median	26.5	1.41	15.00
StDev	7.2	0.78	4.16	StDev	6.2	0.48	4.67

**Table 7.1** Pre-task Book and Hypertext groups matched on Age, CSA (WA) and Shapes Analysis Test score.

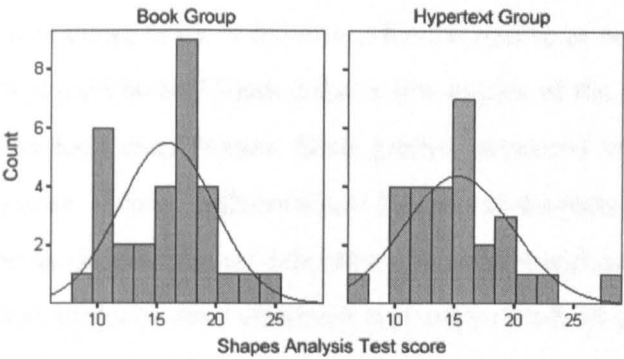
Frequency distribution bar charts for age, CSA (WA) score and Shapes Analysis Test score can be seen in Figure 7.1, 7.2 and 7.3 respectively.



**Figure 7.1** Age bar chart for subjects assigned to Book and Hypertext groups.

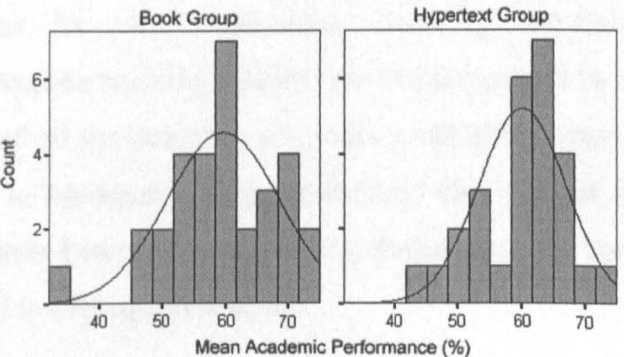


**Figure 7.2** CSA wholist-analytic scores bar chart for subjects assigned to Book and Hypertext groups.



**Figure 7.3** Shapes Analysis Test score frequencies for subjects assigned to Book and Hypertext groups.

In addition to the above variables used to match the groups prior to the experiment, mean academic performance was obtained post-hoc at the end of the academic session. This recorded a subject’s mean percentage score (over 8 modules studied) at the end of their postgraduate diploma. Although not directly comparable, this variable was considered important for its potential relationship with intellectual ability. A frequency distribution bar chart plotting mean academic performance for Book and Hypertext groups can be seen below in Figure 7.4. An independent samples T-Test confirmed that no significant differences existed between the two groups on this variable.



**Figure 7.4** Mean Academic performance percentages bar chart.

Two weeks after the initial cognitive measurements, Book and Hypertext groups, under controlled conditions, were given Task 1 (closed questions), followed one week later by

Task 2 (open questions). Subjects in both groups were not given access to *Human Computer Interaction* in either book or hypertext format before or between experimental sessions. However, it should be highlighted that a few copies of the book were available in the library for short loan consultation. Both groups answered the questions in each task using pen and paper without collaboration. Hypertext subjects were supervised by the author of this thesis, in a computer laboratory with identical hardware and display configurations<sup>19</sup>. Book subjects were observed and supervised, in parallel sessions, by the author's Director of Studies. Before beginning Task 1, subjects in both conditions were given a verbal description of the important features of their assigned medium. Hypertext subjects were also given a five minute practical demonstration of these features being used. Concise paper-based notes explaining the main features of each medium (see Appendix F and G) were issued to both groups with the instructions that they could be referred to at any time during the tasks. Eight minutes were provided to answer five warm-up questions. Any difficulties were addressed before the Task 1 question booklet was issued. Forty minutes were allocated to answer as many questions as possible, but subjects were told that they were not expected to complete Task 1. For Task 2 a total of fifty minutes was allowed and subjects were asked to attempt all four questions.

Task 1 was marked by the current author only, because inter-marker reliability was not considered an issue for closed questions. Task 2, however, required greater interpretation so a detailed marking scheme was developed and two markers used. The current author marked all answers, then a random set of half the papers was marked by a research supervisor independently. Group allocation data was not given to the second marker. A high positive Pearson correlation was found ( $r=0.89$ ). The marks awarded by the author were used in subsequent analysis.

Two weeks after the completion of Task 2, a follow up questionnaire was issued during a feedback session with the class. The role of the questionnaire was to gather opinions

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<sup>19</sup> IBM compatible computers with Pentium 90MHz processors, 16Mb RAM, screen resolution of 1152 x 864 x 256 on 17" monitors. Times New Roman font was used for body text with subjects free to choose

and perceived usability ratings from the subjects to supplement the quantitative data from the task performance scores.

### 7.3 Results

#### 7.3.1 Psychological Results

Correlations between the cognitive styles, spatial ability and the other measures, such as age, were calculated. As Table 7.2 shows, the only significant correlation found was between the Shapes Analysis Test scores and GEFT ( $r=0.56$ ,  $p<0.001$ ). This was somewhat unexpected since the GEFT does not require any mental rotation of figures.

	Sex	Age	Acad. Per.	GEFT	CSA (WA)	CSA (VI)	Shapes Analysis
Sex	1.00						
Age	0.09	1.00					
Academic Performance	-0.16	0.12	1.00				
GEFT	0.08	-0.23	0.13	1.00			
CSA (WA)	0.15	-0.07	0.09	0.10	1.00		
CSA (VI)	0.07	-0.15	-0.16	0.09	0.25	1.00	
Shapes Analysis Test	0.03	-0.19	0.14	0.56*	0.02	-0.02	1.00

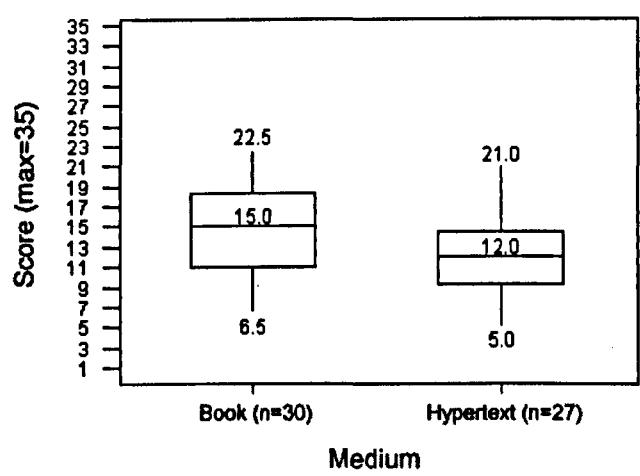
\*  $p<0.001$

**Table 7.2** Correlation matrix of individual differences (n=59).

either ‘Normal’ size - 14pt or ‘Large’ - 16pt.

7.3.2 Task 1: Information Retrieval

The mean number of questions answered (attempted), for each condition, within the 40 minutes allotted were – Book: 17.9 (SD=7.2) and Hypertext: 12.8 (SD=7.6). Using the Mann-Whitney test this difference in the number of questions answered proved to be significant ( $p=0.003$ ). Although, the mean number of questions attempted differed, as expected, the accuracy<sup>20</sup> of the two groups was very similar: Book – 77.2% and Hypertext 76.8%. Marks were awarded for correct answers (no marks were deducted). The mean score of subjects assigned to the Book condition was 15.1 (SD=4.2), while the mean score of subjects assigned to the Hypertext condition was 11.7 (SD=3.8). These scores can be seen visually displayed in the box plot shown in Figure 7.5. The range of marks is indicated by the vertical line – Book: 6.5 to 22.5 and Hypertext: 5 to 21. The box shape within the vertical line represents the range of marks between the first quartile (bottom line of box) and the third quartile (top line of box). The lines within each box shape represent the medians for each group (Book 15.0 and Hypertext 12.0).



**Figure 7.5** Boxplots displaying medians and the range of scores on Task 1 for the Book and Hypertext groups (Book n=30, Hypertext n=27).



To determine whether the performance of subjects assigned to the two groups differed significantly a univariate analysis of variance was performed. Experimental group was included as a factor in the model and, as Table 7.3 shows, accounted for 8.6% of the variance in task score with a significance of  $p=0.048$ . Mean academic performance ( $p=0.004$ ) and age ( $p=0.049$ ) were also found to be significant, accounting for 17.3% and 8.6% of the variance respectively.

Variable	Significance	Effect
Mean Academic Performance	0.004	17.3
Experimental Group (Book/Hypertext)	0.048	8.6
Age	0.049	8.6
CSA (WA)	0.273	2.7
GEFT	0.980	0.9
Sex	0.750	0.2
Shapes Analysis Test	0.533	0.0
Corrected Model	0.005	37.3

**Table 7.3** Univariate Analysis of Variance showing the significance and effect of each variable, including experimental group. Variables reaching 95% significance are shown emboldened.

In order to determine whether any intra-group relationships between task performance and individual difference variables occurred, two further univariate analyses of variance were performed. Table 7.4 shows the results from an analysis of data resulting from the Book condition. It shows that only the mean academic performance of an individual relates ( $p=0.012$ ) to their performance in Task 1 (approximately 27%). Using a simple Pearson correlation it was found that this was a positive relationship whereby those individuals with higher mean academic performance tended to perform better in Task 1.

<sup>20</sup> Number of questions answered correctly compared to the total number of questions attempted.

Variable	Significance	Effect
<b>Mean Academic Performance</b>	<b>0.012</b>	<b>26.5</b>
Shapes Analysis Test	0.231	6.8
Age	0.473	2.5
Sex	0.618	1.2
CSA (WA)	0.622	1.2
GEFT	0.713	0.7
Corrected Model	0.076	39.3

**Table 7.4** Univariate Analysis of Variance showing the relationship of key variables to the Task 1 performance score of subjects assigned to the Book group. Variables reaching 95% significance are shown emboldened.

7.2.3 Task 1: Open-Ended

In a second univariate analysis of variance, using data from the Hypertext group, it was found that no variable reached the standard 95% level of significance. However, as Table 7.5 shows, age ( $p=0.095$ ) and prior computing experience ( $p=0.124$ ) accounted for most of the variance. Prior computing experience, which measured in years the total accumulation of school, university, home and work computer experience, was obtained after the experimental sessions using the questionnaire presented in Appendix D. No significant correlation was found between the age of the subjects and their level of prior computer experience.

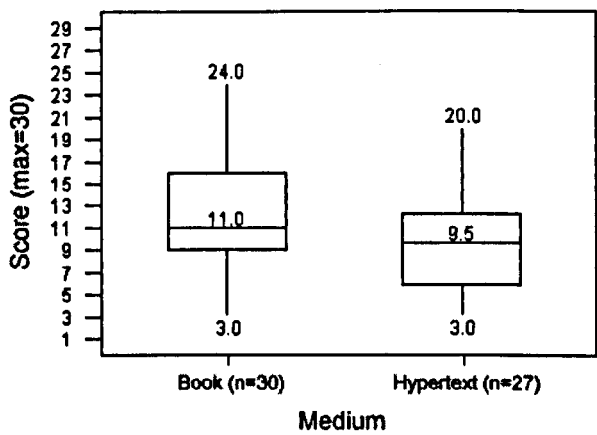
Variable	Significance	Effect
Age	0.095	18.6
Prior Computing Experience	0.124	16.1
Shapes Analysis Test	0.256	9.1
Sex	0.264	8.8
CSA (WA)	0.524	3.0
Mean Academic Performance	0.571	2.4
GEFT	0.584	2.2
Corrected Model	0.076	39.3

**Table 7.5** Univariate Analysis of Variance showing the relationship of key variables to the Task 1 performance score of subjects assigned to the Hypertext group.

After answering each question subjects were asked to tick one of three boxes (see Appendix B) to give a rough idea how long they took to answer it. In general, subjects assigned to the Book condition answered most questions faster. Exceptions included: a) the question “What does CLG stand for?” which was only listed in the Index in full under ‘Command Language Grammar,’ b) “Who is Norman Potts?” Norman Potts was not mentioned in the document, and c) “Name the freelance writer who uses a computer on a bike.” - the key words ‘bike’ and ‘cycle’ did not lead to the answer, only ‘bicycle’ could be used in the Find facility of the hypertext (‘bicycle’ was not indexed).

7.3.3 Task 2: Open Questions

Before any detailed statistical analysis was performed on the data from the second task, the open questions, a simple boxplot was created to visualise the range of marks from the Book and Hypertext groups. As Figure 7.6 reveals, the lowest score in both groups was 3, and the highest score in the Book group was 24 compared with 20 for the Hypertext group. The two boxes show the first and third quartiles together with the median of each group.



**Figure 7.6** Boxplots displaying medians and the range of scores on Task 2 for the Book and Hypertext.

To establish whether the two experimental groups differed significantly in their scores, a univariate analysis as for Task 1 was performed. As Table 7.6 shows, the significance of

the experimental group the subjects were assigned to did not reach the standard statistical 95% level ( $p=0.063$ ). However, this level of significance indicates the possible existence of a trend towards Book subjects performing better than their Hypertext counterparts.

Variable	Significance	Effect
Experimental Group (Book/Hypertext)	0.063	8.6
Sex	0.094	7.0
Mean Academic Performance	0.510	1.1
GEFT	0.688	0.4
CSA (WA)	0.762	0.2
Age	0.808	0.2
Shapes Analysis Test	0.866	0.1
Corrected Model	0.063	20.3

**Table 7.6** Univariate Analysis of Variance showing the relationship of key variables to the Task 2 performance score of subjects assigned to both groups.

To help explain why this trend might have developed, a word count was performed for both experimental groups. Table 7.7 displays the percentage of subjects providing an answer for each question, and below this the mean number of words written. Since the number of Hypertext subjects providing answers to questions three and four was less than the book, mean word counts were also recalculated with all zeros removed (non-attempts). The only significant difference found between these adjusted means was for Question 3 (Book 66.8 and Hypertext 88.7,  $p<0.05$ ). However, overall there were no significant differences between the total number of words written by Book ( $m=240.3$ ,  $SD=106.8$ ) and Hypertext ( $m=232.4$ ,  $SD=108.1$ ) subjects.

		Q1	Q2	Q3	Q4	Overall means
Book	% of subjects providing an answer	93%	100%	97%	69%	89.8%
	Mean word count	73.1	66.4	64.5	36.2	240.2
	Mean word count (zeros removed)	78.6	66.4	66.8	52.5	264.3
Hypertext	% of subjects providing an answer	91%	91%	73%	45%	75.0%
	Mean word count	78.0	67.2	64.5	22.7	232.4
	Mean word count (zeros removed)	85.8	73.9	88.7	49.9	298.3

**Table 7.7** The percentage of subjects providing an answer for each question, the mean number of words written per question, and the mean number of words written with non-attempts (zero words) removed.

Two further univariate analyses of variance were performed on each experimental group separately to establish whether certain variables could be used to predict the differing performance of the two groups. As Table 7.8 shows, only one variable, CSA (Wholist-Analytic), was found to be a significant ( $p=0.012$ ) factor in predicting the Task 2 performance of Book subjects. A Pearson correlation between CSA (WA) and Task 2 score showed that the relationship was negative indicating that lower CSA (WA) score (i.e. more Wholistic in style) tends to result in higher task score.

7.2.4 Questionnaire

Variable	Significance	Effect
<b>CSA (WA)</b>	<b>0.012</b>	<b>27.4</b>
Shapes Analysis Test	0.076	14.9
Mean Academic Performance	0.104	12.7
GEFT	0.107	12.5
Age	0.489	2.4
Sex	0.774	0.4
<b>Corrected Model</b>	<b>0.008</b>	<b>54.9</b>

**Table 7.8** Univariate Analysis of Variance showing the relationship of key variables to the Task 2 performance score of subjects assigned to the Book group. Variables reaching 95% significance are shown emboldened.



A second univariate analysis of variance, as shown in Table 7.9, revealed a different picture for the Hypertext group. Instead of CSA being an important factor, sex and mean academic performance were the only variables found to significantly account for Task 2 variance. Females were found to outperform males and those individuals with higher mean academic performance also tended to perform better on Task 2.

Variable	Significance	Effect
<b>Sex</b>	<b>0.023</b>	<b>36.0</b>
<b>Mean Academic Performance</b>	<b>0.043</b>	<b>30.0</b>
GEFT	0.110	19.9
Prior Computing Experience	0.164	15.5
CSA (WA)	0.305	8.7
Shapes Analysis Test	0.342	7.5
Age	0.723	1.1
<b>Corrected Model</b>	<b>0.007</b>	<b>75.1</b>

**Table 7.9** Univariate Analysis of Variance showing the relationship of key variables to the Task 2 performance score of subjects assigned to the Hypertext group. Variables reaching 95% significance are shown emboldened.

7.3.4 Questionnaire

The questionnaire (see Appendix D) collected a range of quantitative and qualitative data concerning computer experience and attitudes to various aspects of the assigned medium. The questionnaire was completed and returned by 79% of the book group and 67% of the hypertext group (48 responses in total). Some of the more important findings are reported below:

- A. All bar one of the Hypertext subjects had previously experienced other hypertext systems (Question 4): 82% had used the World Wide Web, 86% used online help systems, and 3% had used HyperCard before.

- B. When asked which medium subjects preferred to read from (Question 5), 72% chose paper, 4% VDU, and 24% said either paper or VDU. Although a high resolution (1152x864 at 72Hz) was used on all computers displaying the Hypertext, this still compared poorly with the contrast and resolution of the typeset Book.
- C. Although, as expected, most subjects reported that they would prefer to read the paper version of the book, when asked about learning future topics (Question 12), 55% of the hypertext group stated they would prefer a book, 9% hypertext, and 36% said either book or hypertext. Only hypertext subjects were asked this question since book subjects had not used the hypertext system used in the experiment.
- D. No significant differences in response were found in Question 6: “In general did you enjoy using the document type assigned to you?”. Table 7.10 shows book and hypertext totals for each category and related percentages.

	Not Much	Moderately	Very Much
Book	6 (26%)	13 (57%)	4 (17%)
Hypertext	7 (32%)	12 (54%)	3 (14%)

**Table 7.10** Responses to Question 6 “In general did you enjoy using the document type assigned to you?” with percentages shown in parentheses.

- E. No significant differences were found when subjects were asked, “Did you experience any difficulties getting to any pages/nodes?” (Question 7). Twenty-three percent of both Hypertext and Book subjects reported that they experienced “Many” difficulties getting to pages/nodes. This result was somewhat surprising. The problems of becoming lost in hyperspace have been well documented in the hypertext literature. However, it is commonly believed that finding information in books is much less problematic. The questionnaire results certainly suggest that for unfamiliar domains and for unfamiliar books this is not the case.

F. Question 10, “What do you see as the main advantages and disadvantages of using the document type you were assigned?” was designed to elicit the actual perceived advantages and disadvantages. The main issues raised by Hypertext subjects are listed first, followed below by the responses of Book subjects.

***Hypertext Advantages:***

- Speed
- Enjoyment
- ‘Lighter’ than wading through a book
- Quick searching
- Hypertext links
- Bookmarks
- Copying sections of text
- More users can access a single title in hypertext form than traditional paper format

***Hypertext Disadvantages:***

- Eye strain (5 subjects)
- Easy to become lost (3 subjects)
- Difficult to assess the scope of the book
- Cannot ‘flick’ through the nodes (3 subjects)
- No sense of having been to any pages previously
- Noisy environment in the computer lab

The main comments from Question 10 for the Book subjects were:

***Book Advantages:***

- Familiar (6 subjects)
- Well structured
- Information ordered sequentially
- Reader can flick through pages



- Easy to read
- Remember the spatial location of images and text on various pages

***Book Disadvantages:***

- Difficult to find specific pieces of information (especially when not indexed)
- No 'Find' facility (3 subjects)
- Slow to use large books
- Bulky
- No cues given concerning related information

## 7.4 Discussion

This section begins by considering the importance of correlations between the individual differences used (Section 7.4.1). One of the limitations of tests employed by cognitive psychology is that there is a 'distance' between what the test instruments measure and the underlying personal difference. Gardner (1999), commenting on tests of intelligence, suggests that psychologists must use tests that are 'intelligence fair' and not, as he puts it, testing through the lenses of linguistic or logical intelligences. Taking the Group Embedded Figures Test (GEFT) as an example, this is designed to measure a style of cognitive processing labelled 'field-dependence'. However, it does not directly measure brain activity to determine this style, instead it *infers* style from the number of pattern tracing tasks performed correctly. Not only is there an obvious gulf between the test instrument and the phenomenon being measured, but also there is debate within psychology concerning the nature of its many theoretical constructs. For example, as reported in Section 3.4.1, intelligence and cognitive style are two distinct constructs, artificially created to try and describe an individual's capacity for and methods of processing stimuli. However, many researchers have reported significant positive correlations between field-dependence/independence cognitive style and intelligence tests (Rosenberg, Mintz & Clark, 1977; Riding & Pearson, 1994). This highlights, to some extent, the current artificiality of trying to name and demarcate various cognitive

processes. Thus, in the course of the current research it was considered important to determine whether there were any significant correlations between the test instruments used.

Following an intra-test analysis, Section 7.4.2 considers the important findings arising from statistical analysis of the cognitive tests and performance resulting from the two treatments (Book and Hypertext). A discussion of the relationship between the individual differences and the type of task being performed is included.

The results obtained from the questionnaire are discussed in Section 7.4.3. Importantly many of the comments and responses support suppositions made about task performance measures and observations. This subsection concludes by highlighting an interesting finding concerning the effect each medium had on subjects' perceptions of the other medium.

We conclude, in Section 7.4.4, by turning from the human differences side of the equation to the effect the user interface can have on performance. Although no firm conclusions are reached concerning the importance of the user interface, the main differences between Book and Hypertext are summarised and suggestions are made as to how these differences might affect performance.

### **7.4.1 Relationships between Psychological Tests**

As Table 7.2 shows, only one Pearson correlation was found to be significant, the positive correlation ( $r=0.56$ ) between scores on the GEFT and Shapes Analysis Test. At first glance, a single correlation between different tests appears normal; the tests after all are designed to measure different facets of an individual's psychological makeup. However, upon closer examination, two important issues are uncovered. The first concerns the difference in what the GEFT and Shapes Analysis Test measure. GEFT measures the cognitive style, field-dependence, by a series of non-rotational geometric

tasks, whereas the Shapes Analysis Test is reported to measure spatial ability by requiring subjects to mentally rotate and assess geometric shapes. Although both tests involve geometric shapes as part of their tasks, it is unexpected for such a significant correlation to occur ( $r=0.56$ ,  $p<0.001$ ). One explanation could be that both identification of geometric shapes on complex backgrounds and shape rotation stem from the same basic shape processing cognitive functions. The second question concerns the absence of a significant correlation between GEFT and CSA Wholist-Analytic dimension. Since Riding and Cheema (1991) claim that the Wholist-Analytic dimension of CSA measures the same type of cognitive style as field-dependence (see Table 3.2), a significant positive correlation was expected. The absence of a significant correlation in the current research is similar in some ways to the findings of Riding and Pearson (1994). They found that the Test of Embedded Shapes (TES), another field-dependence/independence measure, did not correlate significantly with the CSA Wholist-Analytic dimension. In this case Riding and Pearson argue that the construct of field-dependence is theoretically sound but question the reliability of using the TES instrument to assess this particular cognitive style. Returning to the current research, not only was there no significant correlation between the CSA Wholist-Analytic dimension and GEFT, but there was no correlation between the CSA (WA) dimension and the Shapes Analysis Test either. It could be argued that if there is some sort of relationship between GEFT and the Shapes Analysis Test, and if CSA measures a similar style to GEFT, then there should be a correlation between the Wholist-Analytic dimension and the Shapes Analysis Test. Speculating, the absence of any correlation between Wholist-Analytic and GEFT could be due to one of two possibilities. The first is in the difference between Riding and Cheema's (1991) work and the current thesis. For example, Riding and Cheema conclude that several 'different' cognitive styles are measures of similar tendencies by reviewing the descriptions, correlations, methods of assessment and effect on behaviour between the terms. They then go on to discuss their own Cognitive Styles Analysis (CSA) system for measuring the two fundamental cognitive styles that they propose. However, nowhere do they report evaluating correlations between this new measure and previous individual cognitive style measures. The approach taken by the work reported in this thesis was not theoretical, like Riding and Cheema's, but empirically based. A

second reason why the results of these two studies differ might be due to the small number of subjects involved in the current research. The styles of only 59 subjects were compared in the research discussed by this thesis. As will be discussed in Section 9.2.1, further work is needed to clarify the relationship between the traditional measures of cognitive style and the newer CSA test.

Analysis of the literature reveals that males are often slightly more field-independent (Maccoby & Jacklin, 1974) and better at spatial rotation tasks than females (Kellogg, 1995). The current research involving a total of 40 males and 19 females found that males did tend to be more field-independent and better at spatial tasks than females but that these differences did not reach significance. The reason for this is probably due to the small number of subjects tested. It is also possible that the females who were attracted to study computing were perhaps more able in this regard than females in general.

#### **7.4.2 Relationships between Medium, Individual Differences and Performance**

Before discussing the results in detail, it was interesting to discover a large difference in the participation rate of the two groups between Task 1 and Task 2. All subjects were asked to attend both tasks. However, two Book subjects did not attend the second task compared with seven Hypertext subjects. This result was the opposite of what might have been expected. Using post-graduate computer subjects, the researchers expected difficulty in motivating individuals to use the book. The higher dropout rate between the two tasks on Hypertext perhaps indicates resistance to hypertext resulting from usability problems experienced during the first session.

Reviewing the data presented in Tables 7.5 to 7.9 it is interesting to note the major differences between experimental groups and tasks. For example, large differences in which individual difference variables were significant and the overall power of the models (Corrected Model figure at the bottom of each table) can be seen across both

groups and tasks. In Task 1 only one variable (mean academic performance) was found to predict a significant amount (26.5%) of subjects' performance in the Book group (see Table 7.4). However, in contrast, none of the seven variables measured for the Hypertext group reached significance predicting any of the variance in Task 1 score (see Table 7.5). Unfortunately the lack of common predictive individual difference variables across tasks and media limits the potential utility of these variables to inform educational content design and user interface design.

The remaining part of this section will discuss each individual difference separately, followed by a discussion of the results from the multiple regression analysis.

### *Spatial Ability*

Research reported by McGrath (1992) and Höök, Sjölander and Dählback (1996) together with a meta-analysis of hypertext studies conducted by Chen and Rada (1996) points towards the importance of spatial ability as a variable closely assigned to navigational efficacy in online textual environments. Unfortunately the results from the current research are at odds with these previous studies. Spatial ability, as measured by the Shapes Analysis Test, was not found to account for a significant amount of the variance in Task 1 score for subjects assigned to either the Book or the Hypertext experimental groups. One possible explanation for these findings might be that the information retrieval questions which formed Task 1 do not actually require subjects to process much spatial information. This is borne out to a certain extent by observation of each group. The Book group concentrated mainly on using the Index while Hypertext subjects used the Find facility most often during Task 1. Halasz (1988), referred to earlier in Section 4.4.7, posited that users can often describe the information they require but not how to find it in the network. Using either the Index or Find facilities subjects can jump straight to various part of *Human-Computer Interaction* without much understanding or appreciation for the surrounding textural topology.

In contrast it was expected that spatial ability would be more important in the second experimental task. Each question required subjects to consult multiple sections in order

to synthesise an appropriate answer. For example, the first question of Task 2 required subjects to name a development life cycle appropriate for the development of a PDA device and to state their reasons for their selection. This requires information from Chapter 11 about Input, Chapter 12 on Output and Section 2.4 and Chapter 18 about development life cycles. Each question was suitably phrased so that subjects could not simply consult the Index and find a single part of the book and copy the text verbatim. A greater appreciation for the structure of the book and how the various chapters are related to each other would have been an advantage. Contrary to expectations the correlation between Shapes Analysis Test score and score using Book and Hypertext for Task 2 did not reach significance. The univariate analysis of variance in Table 7.8 indicates a weak relationship ( $p=0.076$ ) between spatial ability and the Task 2 performance of the Book subjects. A Pearson correlation confirmed that the relationship, as expected, was positive indicating that subjects with higher spatial ability tended to perform better in Task 2. What is unknown is why spatial ability was not an important factor in this second task for the Hypertext group. Further research is required to determine exactly what part of the task/hypertext interplay is related to spatial ability. Although as mentioned above many researchers (Chen & Rada, 1996; Höök, Sjölander & Dählback, 1996; McGrath, 1992) found relationships between hypertext performance and spatial ability, the data from the current study suggests that it is premature to suppose that spatial ability is always an important factor for all hypertext systems.

### *Cognitive Styles*

Although many studies (Leader & Klein, 1996; Korthauer & Koubek, 1994), as highlighted in Section 4.6.2, have found significant differences in performance when analysing the interplay of cognitive styles and various hypertext facilities, the current research does not support the proposition that cognitive styles are the most important type of individual difference. The only cognitive style found to predict a significant amount of task performance was the CSA Wholist-Analytic dimension. As Table 7.8 showed above, CSA (WA) accounted for approximately 27% of the Task 2 variance in subjects assigned to the Book group. What is surprising is the lack of significance for this variable when analysing the Task 2 performance of subjects assigned to the

Hypertext group. In this case Sex and Mean Academic Performance were the only significant factors to account for Task 2 variance in the Hypertext group. Not only was it found that CSA (WA) did not predict significant amounts of Task 2 performance between the groups, but it was also not found to be significant in predicting Task 1 performance. Like spatial ability, the tendency for subjects to perceive stimulus material as a whole or in more focused parts may be an unimportant factor when utilising the Index or the Find facility and therefore effectively ignoring the underlying structure of the document. As well as CSA, GEFT was the other measure of cognitive style. However, the influence of this style on either the Book or Hypertext groups or on Task 1 or Task 2 performance did not reach significance. This finding is at odds with the results of Leader and Klein (1996) who found that field-independent subjects performed significantly better than field-dependent subjects when using a hypertext system with only an Index and Find. They found that when subjects were given a choice of which navigational facility to use in the 'all' condition (Browser, Index/Find and Map), there were no significant differences between field-dependent and field-independent subjects. Although it could be argued that the hypertext version of *Human-Computer Interaction* is most similar to Leader and Klein's 'all' condition, personal observation by the author suggests that the Find was used most for Hypertext subjects answering Task 1 followed by some use of the Index. Little browsing using the hierarchical structure of the book was evident during the first task. However, the insignificant differences between field-dependent/independent styles and the performance of subjects in Leader and Klein's 'all' condition does support the findings of Hypertext subjects' performance on Task 2. In this task most Hypertext subjects were seen to use a wider variety of navigational techniques including the Index, Table of Contents, Find and browsing using hypertext links found on each page. Further support for the lack of any significant differences comes from Liu and Reed (1994). They found that although subjects with different cognitive styles (field-dependence/independence) employed different learning strategies, their performance on an experimental achievement test was not significantly different. This led Lui and Reed to conclude that hypermedia has the potential to accommodate learners with different learning styles through the use of various features (e.g. video to support field dependent learners and an index to support field independent learners).

### ***Mean Academic Performance***

Mean academic performance, obtained post-hoc, represents the overall mean percentage awarded to each subject for coursework and exam results over the whole post-graduate diploma course. Interpretation of this variable is difficult since there is an interplay between medium and task. Overall as Table 7.4 shows, mean academic performance accounted for more variance (17.3%) in Task 1 score than the effect of age (8.6%) and medium (8.6%) put together. This suggests that the characteristics that are associated with a subject performing well on their degree as a whole are similar to those characteristics that are required to perform information retrieval tasks under time pressure. Further research is necessary to determine the constituent parts of mean academic performance. It could be, for example, that there is a close relationship with mental abilities (e.g. linguistic intelligence). However, when mean academic performance was analysed for each task and medium individually an unexpected interaction was found. Mean academic performance was a significant factor predicting the Task 1 performance of the Book group and the Task 2 performance of the Hypertext group. Although it is not possible to be certain exactly why this occurred from the current data, it appears that mean academic performance probably constitutes more than intelligence. Intelligence is value directional, so having more intelligence would benefit both tasks for both groups. Instead mean academic performance is probably more likely to be a measure of successful learning style resulting from a specific interplay between an individual's cognitive style and their mental abilities. Further work is undoubtedly required to clarify this situation.

### ***Sex***

As the tables in the previous section show, sex was included as one of the individual difference variable analysed. In general sex was not found to be a significant variable in predicting Task 1 or Task 2 score. The exception to this, as seen in Table 7.9, was a significant relationship between sex and the Task 2 score of subjects assigned to the Hypertext group. Female subjects scored higher marks than the male subjects. This finding was unexpected for two main reasons. Firstly sex was only significant for one



task (Task 2) and for one experimental group (Hypertext). It seems reasonable to assume that if there was something innately beneficial in either medium then the importance of sex would appear in one group for both tasks. Conversely, if something in the composition of the task favoured one particular sex then the significance should be observable in both experimental groups. The second reason making this difference between the sexes surprising was that the results from the current research are at odds with those reported by other studies. For example, Ford and Miller (1996) studied 40 male and 35 female university students completing a number of Internet-based tasks. They found that the females reported significantly greater levels of disorientation and disenchantment with the Internet in comparison to the males. In another study, using data collected in 1992, it was found that school aged females knew less about information technology, enjoyed using computers less, and perceived more software problems than males (Reinen & Plomp, 1997).

In an attempt to objectively explain why the female subjects in the current study performed significantly better than male subjects in the Hypertext group on Task 2, the male and female groups were analysed for any significant differences on the other variables measured. It is unlikely that sex alone was an important factor, rather it seems more plausible that some other individual difference factor, for example spatial ability, influenced performance. Using the Mann-Whitney test no significant differences in GEFT, CSA (WA), Age or Shapes Analysis Test score were discovered between male and female subjects in the Hypertext group. However, although the mean academic performance of subjects as a whole (male and female) were not significantly different between the Book and Hypertext Groups, there was found to be a significant difference between the mean academic performance between the sexes within the Hypertext group. The mean academic performance of females was 4.1% higher than that of the males on average ( $p=0.04$ ). Since the mean academic performance was found to be a significant predictor of Task 2 performance (see Table 7.9), it is reasonable to conclude that it may be this difference that contributed to the significance of sex. Given the current priority and status afforded hypertext in most university's e-Learning strategies, the current

research joins the call made by Ford and Miller (1996) for further empirical research into any possible sex differences in relation to these online text systems.

### *Age*

As Table 7.3 above shows, the age of a subject, for Book and Hypertext groups combined is related to their Task 1 performance. The importance of age as a predictive variable disappears when analysing the Book group alone, but it is suggestive of a trend with the Hypertext group. Given that age was not found to be a factor for either experimental group completing the second task, it appears likely that it is a characteristic of Task 1 which makes this individual difference important. In order to see if the speed of answering was related to age three Pearson correlations were computed between the number of questions attempted and subjects' ages. The values of  $r$  from comparing all subjects together (Book and Hypertext) and the Book group alone are too low to reach significance. However, the figure obtained for the Hypertext group ( $r=-0.279$ ) falls just short of the 90% significance level indicating the existence of a possible trend towards older subjects interacting with the Hypertext slower than younger subjects. Mead, Spaulding, Sit, Meyer and Walker (1997) found significant differences in the efficiency of searching between younger and older users. However, their older group, aged between 64 and 81, were significantly older than the subjects used in the current study. Also, Mead *et al.* only report significant differences between the two age groups when the optimal path was long (3 to 6 links). Given that nearly all questions in Task 1 could be completed using optimal paths of 1 or 2 links together with some scrolling of the window, it seems unlikely that Mead *et al.*'s. conclusion that older subjects had difficulty remembering previously visited links is appropriate to the current research. However, the work of Westerman, Davies, Glendon, Stammers and Matthews (1995) is revealing. They compared the performance of older and younger users on four different text structures and found a large difference (nearly twice as long) in response times for older users completing the first block of questions. Although the difference never disappeared, the gap closed substantially from the second question block onwards. This led Westerman *et al.* to suggest there could be an initial difference in forming a mental representation of the information space between the two age groups used in the

research. If true, this could explain why age was important for Hypertext subjects completing Task 1 but not Task 2. However, it does not explain why age was not important for Task 1 with the Book group. One possibility is that use of books is so familiar, age differences are no longer a significant source of variance.

### *Prior Computing Experience*

Prior computing experience was only recorded and analysed in conjunction with the performance of subjects assigned to the Hypertext group. Although all the Book subjects possessed prior computing experience it was assumed that this individual difference would not be an important factor in affecting the performance of this group. As Table 7.5 showed above, prior experience of computers was found to weakly relate to the Task 1 scores of the Hypertext subjects. Although the probability, in this case only 0.124, is much weaker than the standard 95% level of significance, this finding is still of interest. Apart from age, prior computing experience is the only variable with a high enough level of significance to warrant further investigation. Age is more significant, but this is one of the individual differences that is uni-directional and constantly changing in everyone. Although systems can be adapted to match the changing physical and cognitive abilities of a person as they age, it is not possible to actually change their age. However, experience of computers is very easy to manipulate by training courses and practice sessions. The discovery of this tentative relationship between prior computing experience and Task 1 score was somewhat unexpected since all subjects had at least six months fairly intensive experience of computers, being in their second semester of a post-graduate IT conversion course, and all indicated that they had used some form of hypertext previously (e.g. online help system, World Wide Web). One slightly unfortunate aspect of the experiment was that the hypertext system was implemented using WinHelp from Windows 95 instead of Windows 3.1 in order to take advantage of the Find facility and better colour support for graphics. However, the majority of subjects assigned to the Hypertext group did not have prior experience of the Windows 95 operating system. Subjects were provided with instructions explaining the functionality of the new window minimise, maximise and close icons, but a few users were seen to accidentally close the main hypertext window. Interestingly, no significant

correlation were found between prior computing experience and Task 2. Although Gray, Barber and Shasha (1991) found evidence for a learning effect across only five experimental sessions using a type of hypertext system, the chances of a learning effect occurring in the current study is slim. Subjects had five minutes to practice using the Hypertext system and then 40 minutes to complete Task 1. Even if the subjects had improved their performance, the transferability of these newly acquired skills would be somewhat limited given the different nature of the second task. Further work is necessary to confirm whether a learning effect did take place or whether hypertext is less suitable for information retrieval type tasks than books.

### 7.4.3 Questionnaire Findings

The results from the questionnaire (see Appendix D) provide interesting data in addition to the more quantitative task performance data. Most surprising was the finding that prior computing experience appeared to be quite an important variable for Hypertext subjects in Task 1 even though all subjects, apart from one, had existing experience of hypertext and their mean computing experience was 4.5 years. It is also interesting that a similar correlation between computing experience and Task 2 performance was absent. It is reasonable to hypothesize that computing experience was important for the first task because a greater knowledge of specific facilities (such as 'Find' and the ability to use the mouse and control windows quickly) was advantageous, whereas on Task 2 which required more reading and cognitive processing and less emphasis on system operation, computing experience is less important.

Another surprising finding concerned differences between responses to preferred reading medium (paper, VDU or either) and preferred future learning system (book, hypertext or either). Seventy-two per cent of all subjects (Book and Hypertext) stated that they preferred to read from paper, but only 54 per cent of the Hypertext subjects<sup>21</sup> stated that they would prefer to use books when learning future topics. Meyrowitz

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<sup>21</sup> Only Hypertext subjects were asked to answer Question 12.

(1991) outlines fourteen challenges for the hypertext community. Challenge number three is, “Make the screen display exceed paper. Until individuals choose a computer over paper for reading, hypermedia will not catch on.” (p. 310). While this statement, together with comments about eye-strain (discussed further below), may explain the higher dropout rate of Hypertext subjects between the two tasks, it is interesting to note that 46 per cent of Hypertext subjects responded that they would like to use ‘hypertext’ or ‘either medium’ when learning future topics. It would appear that although display technology needs to be much better in order to rival paper, there are already aspects of hypertext (e.g. full-text searching) which ‘compensate’ for some of the more negative aspects of working from screen.

The superiority of paper over computer displays was emphasised again when subjects were asked to describe the advantages and disadvantages of their assigned medium (Question 10). Five Hypertext subjects commented on eye strain and visual fatigue. Other striking differences between Book and Hypertext were also apparent. For example, Book subjects found it difficult to locate information if a topic was not indexed, whereas Hypertext subjects commented that this was a simple task using the ‘Find’ facility. These attitudinal results confirm Leventhal, Teasley, Instone, Rohlman and Farhat’s (1993) quantitative findings that hypertext users were significantly faster than book users when locating non-indexed text. Book subjects from the current study cited familiarity as an advantage when using books. However, becoming lost and not being able to appreciate the scope or volume of the ‘book’ was a problem for Hypertext users. Certain contradictions were also reported. For example, one advantage of books cited was their portability whereas a different subject included bulkiness as a disadvantage.

As already mentioned, difficulty in assessing the scope and volume of the Hypertext system was reported by some subjects. This is consistent with results presented by Hammond and Allinson (1989) who found that by varying the facilities provided (e.g. Map, Index, Tour), the number of screens thought to have been viewed varied as a ratio of screens actually viewed. The closest match between what the subjects believed they

had seen and what they actually viewed was in the hypertext condition which had all facilities present. Several subjects from the current experiment, reported becoming lost in the Hypertext. Although the current branch (location) in the document hierarchy was displayed on all main pages at the top of the screen, scrolling down the page resulted in this contextual map disappearing from view. The Hypertext therefore lacked the positional cues afforded by the physical properties of the open Book. Subjects would probably have benefited from visual cues to emulate the book on screen like those used by Catenazzi and Sommaruga (1994), or the addition of more explicit and visually permanent maps/tables of contents.

One issue worth highlighting from the questionnaire is the influence media can have on each other. They do not operate in isolation as discrete artefacts. For example, several Hypertext users commented on their inability to flick through screens in the Hypertext like they do when reading books. Book users also, because they are familiar with elementary hypertext concepts, raised the point that one of the disadvantages of the Book was that it was slower to use because it did not have any 'Find' facilities. Thus, it is apparent that there is a certain amount of conceptual baggage which users carry between various media. This finding is consistent with those of Wiedenback and Davis (1997) who found that previous software experience influenced users' perceptions of ease of use of newly encountered applications. They recommend that, knowledge of previous user experiences should be considered in the design of software and training programmes. Indeed, it would appear that such advice could be useful to the field of hypertext. Eventually it is likely that hypertext will extend current possibilities, just like desktop publishing did with print technologies, but in this period of transition it would appear that hypertext design could usefully be informed by analysis of successful book interactions.

## 7.4.4 Importance of the User Interface

Although a description of the specific implementation of the hypertext system has already been provided in Section 6.2, it is important to discuss how this hypertext design differs from the book and the impact this could have had on the results presented above.

Book and hypertext employed similar structures: linear and hierarchical. The book contained referential links (network structure) in the form of, for example, ‘see Chapter 8.’ The hypertext implementation supported instant traversal of these links by mouse activation. Both media contained exactly the same text and graphics, the hypertext did not introduce any media beyond the text and graphics present in the paper version. However, although the content was the same in both conditions, the interfaces were palpably different. For example, the book afforded:

- Visual scanning of greater page areas.
- More sophisticated typographical layouts, more white space (see Figure 6.5).
- Use of temporary bookmarks by inserting fingers (both hands employed unlike one-handed mouse operation).
- Use of spatial memory: for example, remembering whether a picture previously seen was on the left or the right hand page.
- Rapid flicking of pages to find previously read material.
- Progress monitoring through the tactile information provided by the physical construction of the book (length of chapters, sections, pages left to read between thumb and index finger).

Conversely, the hypertext environment enabled certain interactions not possible using paper, for example, pop-up nodes to display glossary terms and references without leaving the current place. Black *et al.*, (1992) found that by decreasing the perceived ‘cognitive cost’ users could be encouraged to access more definitions (displayed in pop-up windows). Also provided by the current hypertext system were:

- A full-text search capability (advocated by Halasz, 1988).
- Multiple windows offering a limited form of parallelism (Min, 1994).

Finally, one of the largest differences between the two conditions was that the spatial location of text on each page of the book was fixed, whereas, in the hypertext system, lengthy nodes were presented in scrollable windows thus varying the position of text. Piolat, Roussey and Thunin (1997) found that when using non-scrollable 'pages' on the computer, subjects constructed a much better representation of the text and could find relevant information faster than when text was scrollable. However, the study conducted by Piolat *et al.* involved a text of only 574 words in length. Each screen contained 18 lines of 50 characters. Given that such a design can only display roughly 144 words per page, it would take approximately 1,750 screens in total to represent *Human-Computer Interaction*. Obviously very careful design considerations must be made to permit navigation around such a large number of nodes.

Modern hypertext systems, like books, employ several different complementary access facilities, each more or less important according to the task in hand. Lehto, Zhu and Carpenter (1995) found that when they compared two hypertext systems, one with a manually generated index (MGI) and the other with a computer generated index (CGI), they found subjects using the MGI version were significantly quicker at finding answers, found a significantly greater percentage of answers and scored higher marks than CGI subjects. Subjects were observed, during both experimental tasks, to favour use of Find over the Index. Thus, part of the performance differential between Book and Hypertext may have been caused by Book subjects being forced to use the more efficient manually generated index, whereas Hypertext subjects opted to use the computer generated index (Find facility) more.

Another reason why book subjects performed better than hypertext subjects could be due to a lack of hypertext familiarisation and training time before the experiments. Leventhal, Teasley, Instone, Rohlman and Farhat (1993) and Grey, Barber and Shasha (1991) both found that hypertext performance increased on subsequent experimental



tasks. Grey *et al.* found that hypertext subjects did not perform better than book subjects until the third session. Subjects in the current experiments were given a demonstration of the system, a short practice session, and had reference notes describing the features of the hypertext. Although no subject was seen to experience any significant operational difficulties during either task, the effect of internalised book behaviour versus conscious hypertext behaviour must not be underestimated. The data to some extent show this. For example, Task 1 elicited a significant positive correlation for Book subjects between task score and their overall academic performance, as one would expect. However, with the hypertext group, who were relatively new to the medium, academic performance did not correlate significantly with performance in Task 1. Instead, there was a weak correlation between task performance and previous computer experience. In addition, the fact that those hypertext users were at a significant disadvantage in Task 1, but not in Task 2 is encouraging. However, it is not known whether this was due to greater familiarisation with the hypertext by Task 2 or, like Chan and Rada (1996) found, hypertext is better suited for open questions. Moreover, if it is found that additional training/familiarisation with hypertext is necessary, the period of time required is another question. As already stated, a trend was discovered between prior computer experience and Task 1 performance for the Hypertext group; this was in spite of the fact that all Hypertext subjects had at least six months computer experience (mean=4.5 years, SD=3.3 years).

Finally, it is important to appreciate reading speed differences between paper and CRT. As mentioned in Section 4.5.4, Muter and Maurutto (1991) found that normal reading speeds were similar between paper and CRT, however, skim reading was 41 per cent slower using CRT. Given that subjects had limited time for both tasks it is highly likely that both groups would employ skim reading to a certain extent, thus hypertext subjects may have been at a disadvantage in this respect.

## 7.5 Summary

The experiment discussed in this chapter was designed to investigate two related aspects of learning, firstly the implications of individual differences when using ‘off-the-shelf’ media rather than specially targeted media, and secondly the relative usability of hypertext compared with book, for a large, academic text.

Statistical analysis of the resulting data indicate that individual differences are important factors in learning complex knowledge domains. While the current data on its own does not lead directly to improved hypertext or book design, it can provide a valuable first step in identifying which types of users are disadvantaged in various situations (different tasks). The lack of similarities between significant variables and the two tasks illustrates the tight coupling between individual differences and cognitive activities. This finding argues for the inclusion of specific facilities within a medium that can support different tasks.

The results of a comparison between the two media used in the experiment suggest that books are currently better than hypertext for advanced learning. However, although Book subjects performed significantly better on Task 1 (closed information retrieval) and tended to perform better on the second task (open-ended), it must be remembered that all the Book subjects had extensive experience of books (15 years or more). However, some Hypertext subjects had only been using computers extensively for six months.

So far, this study has added to the growing body of literature concerning book and hypertext comparisons. It has also provided new data about the potential of individual differences analysis to detect problems with what have been referred to here as ‘off-the-shelf’ systems. Given that books are currently under enormous pressures, and the situation looks set to worsen, it is important to consider how the performance of hypertext can be improved and its problems removed or minimised. A review of literature on the subject suggests that changes to the user interface of hypertext can have

significant effects on performance (Lauder *et al.*, 1993; Hammond & Allinson, 1989), and analysis of individual differences is important (Pask, 1976; Riding & Sadler-Smith, 1992; Korthauer & Koubek, 1994), but in comparison relatively little is understood about learning how to use hypertext and the level of performance of experienced hypertext users. Data from the current experiment shows a possible weak relationship between prior computing experience and Task 1 performance (closed questions) for hypertext users, but no relationship on Task 2 (open questions). There are two possible reasons for this change: firstly it could be a function of the nature of the task type, or secondly it shows the presence of a learning effect. Further work is needed to establish the reason. In the next chapter, a second experiment is described which was devised to investigate further the effect of familiarisation on hypertext performance.

## 8. Experiment 2 – Importance of training and familiarisation

“Traditional organizations of information (linear) have persisted for quite some time and to expect students to quickly adapt to nonlinear organizations might be unrealistic. Studies comparing the two structures of information in a computer environment have generally found that nonlinear structures can result in initially lower levels of achievement for some students until they become comfortable and proficient with hypertext formats.”

*(Ayersman, 1996, p. 511)*

### 8.1 Introduction

Data from the first experiment, reported in the previous chapter, points to the superiority of books compared with hypertext when used to support various multi-disciplinary knowledge retrieval tasks. One of the interesting findings from this preliminary study was a possible weak relationship between prior computing experience and the Task 1 performance of Hypertext subjects. However, it was unclear why prior computing experience was not also important for performance on Task 2 as well. Perhaps hypertext is more suited to specific fact finding as required by the first task, or alternatively a learning effect may have occurred. There were reasons to prefer the second possibility. For example, all the hypertext subjects would have used books for at least 18 years, whereas some had only used computers frequently for six months. This substantial difference in periods of use is important when considering the views of Burbules and Callister (1996, p. 48):

“Learning to hyperread is as complex and challenging a task as learning to read in the first place (or, in different words, it is a very sophisticated kind of reading). Part of this process may involve unlearning certain habits associated with reading linear texts, or regarding them as useful only given certain circumstances and purposes. The most important of these changes will be a shift away from a consumer

approach to reading to a co-producer approach to reading, and a shift in one's view of gaining knowledge, away from the passive reception of facts, and towards the active construction of understanding."

A similar view is shared by Barnes (1996), "The literacy required by new media is the most complex form of literacy we can imagine." Citing Lanham (1993), Barnes discusses the difference between the textual interface of a printed book and the new visual elements possible using computers. "Readers no longer look through the *transparent* printed type faces to read a written passage, but they look *at* the decorative page." (Barnes, 1996, p. 11) The reader becomes more conscious of the text itself. However, it could be argued that any person learning the alphabet for the first time is very conscious of each letter. It takes time before an individual can read a sentence fluently without consciously attending to individual letters. Likewise, it could be argued that the performance of hypertext users is currently at the 'conscious' stage where each icon and hyperlink has to be lingered over and subvocalised before deciding upon a suitable course of action.

Practical evidence of learning to use hypertext is somewhat scarce, however, Mayes, Kibby and Anderson (1990b) make an interesting observation:

"The strong impression is gained that subjects either learn to navigate in the hypertext or they learn the instructional material but, at least during the initial stages of use of *StrathTutor* that we have so far studied, they cannot do both together."

Not only does this suggest that the operation of the hypertext had not been internalised, but it also supports the findings of many others (e.g. Conklin, 1987; Foltz, 1996) concerning the increased cognitive load imposed when using hypertext. If the load was less then it would probably have been possible to learn how to use the system and learn the content domain at the same time.

Several hypertext studies have reported learning effects occurring over successive sessions, but few studies have been specifically designed to study this phenomenon in

greater detail. A second experiment was therefore designed to gain a greater understanding of the process of learning how to use hypertext. The design of the experiment, described in further detail below, utilised the same hypertext system and tasks as the first experiment, but gave longer training and familiarisation time to a new set of subjects.

## **8.2 Methods**

### **8.2.1 Subjects**

Eighteen postgraduate student volunteers from Napier University studying Human-Computer Interaction took part in the second experiment. These subjects were studying the same module as those involved in the first experiment, discussed in Chapter 7, but were from the following cohort. It was originally intended to run a repeat of the first experiment, using both Book and Hypertext groups, as before. Unfortunately only four of the subjects assigned to the Book condition attended both experimental sessions. With such a small dataset it was decided that statistical analysis could not be performed. As a result the data and discussion presented in this chapter compares the performance of the 14 Hypertext subjects from Experiment 2 with the performance of the 30 Book subjects and 27 Hypertext subjects from Experiment 1. Eight of the subjects from this second experimental Hypertext group were female and six were male. Their ages ranged from 22 to 40 years with a mean of 27.6 years ( $SD=4.72$ ).

### **8.2.2 Materials**

The hypertext system used in the first experiment was reused so that direct performance comparisons could be made. One small difference was present which resulted from an unavoidable change in computer labs used for the two sets of experiments. The second experiment used computers with 15” monitors and a resolution of 1024 x 768 pixels whereas in the first experiment 17” monitors were used with resolutions of 1152 x 864

pixels. Dividing the horizontal visible width of each display by the horizontal number of pixels revealed that both groups of monitors displayed a resolution of approximately 90dpi. In practical terms the physical size and visual quality of text and graphics should have been virtually identical across experimental labs. The only benefit the higher resolutions monitors from the first experiment would have afforded users is the greater area with which to re-size and position windows in. Both tasks from Experiment 1 were reused without any changes, but the psychological tests were not used. The reason for this was that the aim of the second experiment was primarily to determine the importance of training and familiarisation, not to investigate further the individual differences measured in the first experiment.

### **8.2.3 Procedure**

All subjects were given an introduction to the hypertext system that lasted approximately half an hour. The main principles of browsing, including backtracking, understanding one's current whereabouts within the hypertext, and how links work was described. Searching, bookmarking and annotating were also covered. And it was recommended to subjects that, when looking for information, it is often more effective to use the 'Index' first and then to try 'Find' (search facility) if unsuccessful with the index. In addition to the practical half-hour demonstrations, all subjects were given a small written set of instructions that they could refer to at any time, including during the experiments. A copy of these instructions is included in Appendix G. At the end of the hypertext demonstration, subjects had the opportunity to ask any questions before being advised to practice using the hypertext during the remaining time in the one hour session. Subjects were also told that they could access the hypertext on any computer linked to the relevant server and that they should use it as often as possible in their own time during the two weeks until the first evaluation session Task 1. Although participants understood that they would be required to answer questions concerning HCI, they were not told what any of the task questions would be. Given that subjects in the first experiment did not have access to the hypertext before Task 1 it could be argued that subjects in the second experiment might perform better because they had

acquired more knowledge about HCI. Ideally a hyperdocument employing the same hypertext engine as the first experiment but containing a different subject matter would have been preferable but this was not possible within the time constraints and finances of the research.

## **8.3 Results**

### **8.3.1 Experimental group characteristics**

To avoid confusion between subject groups, hereafter the Book and Hypertext groups from Experiment 1 will be referred to as Book1 and Hypertext1 groups respectively, and the Hypertext group from Experiment 2 will be referred to as Hypertext2.

Before analysing the performance of subjects in Hypertext1 and Hypertext2 groups it was first necessary to determine whether the groups differed in any significant ways. To do this the Mann-Whitney test was used to compare both groups on age and mean academic performance. The age of subjects in the two groups were not found to be significantly different. Unfortunately the mean academic performance of subjects assigned to Hypertext2, which was not available until after the experiment had been carried out, was significantly higher than the mean academic performance of subjects assigned to Hypertext1 ( $p=0.04$ ) and also Book1 ( $p=0.03$ ).

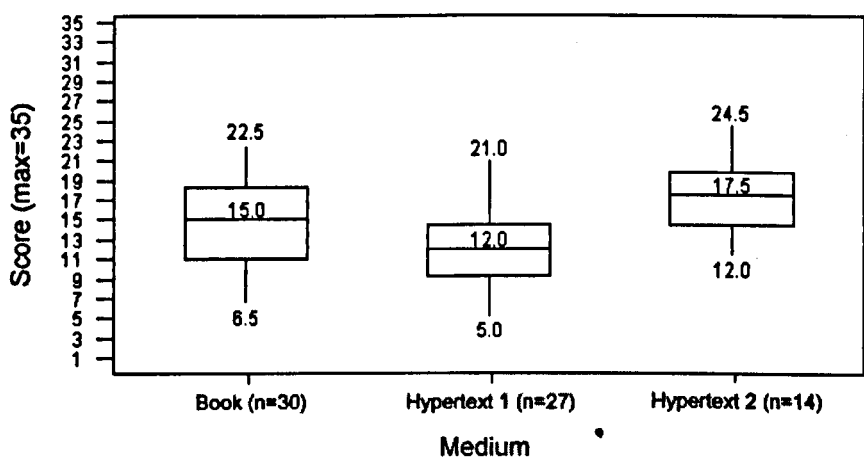
### **8.3.2 Task 1: Information Retrieval**

The mean number of questions answered (attempted) by subjects assigned to the Hypertext2 group was 21.0 ( $SD=3.6$ ) compared with 17.9 for the Book1 group and 12.8 for the Hypertext1 group. Using the Mann-Whitney test to compare the number of questions answered it was found that Hypertext2 subjects did not attempt significantly more questions than Book1 subjects, but they did attempt more questions than subjects assigned to Hypertext1 ( $p=0.001$ ). In addition to the overall number of questions



answered in Task 1, the accuracy<sup>22</sup> was also analysed. As reported in Section 7.3.2, the mean accuracy of subjects in Book1 (77.2%) and Hypertext1 (76.8%) in the first experiment was not significantly different. However, the accuracy of subjects in Hypertext1 compared to Hypertext2 (83.3%) was found to be significantly different ( $p=0.046$ ). Also, the accuracy of subjects in Book1 compared to Hypertext2 approached significance ( $p=0.054$ ). To see if this greater accuracy was related to the higher mean academic performance of the Hypertext2 subjects, a number of Pearson correlations were performed. Separate correlations comparing Book1 accuracy to mean academic performance and Hypertext1 accuracy to mean academic performance both resulted in insignificant values. However, the Pearson correlation of Hypertext2 accuracy and mean academic performance resulted in a value of  $r=0.502$  which was just under the value required for the 95% confidence level.

The overall range of marks for the Hypertext2 group compared to the two groups from Experiment 1 can be seen displayed in boxplot format in Figure 8.1.



**Figure 8.1** Boxplots displaying medians and the range of scores on Task 1 for the first experiment (Book1 and Hypertext1) compared with the second experiment (Hypertext2).

<sup>22</sup> Number of questions answered correctly compared to the total number of questions attempted.

Although the range of marks and median for Hypertext2, as shown above in Figure 8.1, is higher than either Book1 or Hypertext1, further statistical analysis was required given the significant difference in mean academic performance between Hypertext1 and Hypertext2. A Univariate analysis of variance was selected as a suitable statistical method which would allow mean academic performance to be included as a co-variate and thus its effect taken into account between the experimental groups (Book1, Hypertext1, Hypertext2).

The first univariate analysis of variance, shown in Table 8.1, shows the importance of each variable for Hypertext1 and Hypertext2 groups. Three variables were found to significantly predict variance in Task 1 performance. These are displayed emboldened and listed in descending order of significance. The effect column indicates the percentage of Task 1 performance that could be predicted by each variable. The experimental group was most significant and could predict 22.5% of the variance in Task 1 score for Hypertext1 and Hypertext2 subjects.

Variable	Significance	Effect
<b>Exprimental Group (Hypertext1/Hypertext2)</b>	<b>0.004</b>	<b>22.5</b>
<b>Age</b>	<b>0.008</b>	<b>19.5</b>
<b>Mean Academic Performance</b>	<b>0.018</b>	<b>15.8</b>
Sex	0.394	2.2
<b>Corrected Model</b>	<b>0.000</b>	<b>53.6</b>

**Table 8.1** Univariate Analysis of Variance showing the importance of selected variables measured from the Hypertext1 and Hypertext2 groups, as prediction of Task 1 performance.

A second univariate analysis of variance was constructed to determine which variables were important when comparing the Book1 and Hypertext2 groups. Mean academic performance was found to be the only significant variable to predict Task 1 score. Experimental group was found not to be a significant variable in the resulting model.

Variable	Significance	Effect
Mean Academic Performance	0.000	28.3
Age	0.328	2.6
Exprimental Group (Book1/Hypertext2)	0.553	1.0
Sex	0.820	0.1
Corrected Model	0.005	35.4

**Table 8.2** Univariate Analysis of Variance showing the importance of selected variables measured from the Book1 and Hypertext2 groups, as prediction of Task 1 performance.

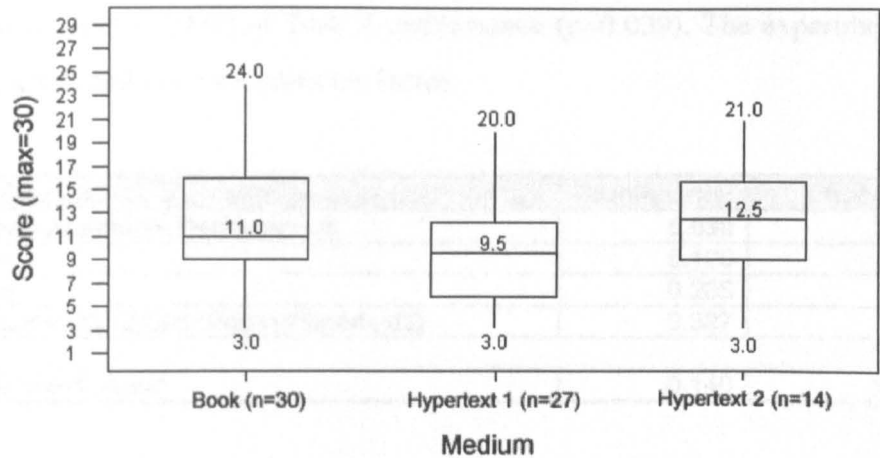
A third univariate analysis of variance was constructed using data solely from the Hypertext2 group. Mean academic performance was the only variable to reach significance and was found to predict approximately 69 percent of Task 1 variance. Prior computing experience, sex and age were all found to be insignificant.

Variable	Significance	Effect
Mean Academic Performance	0.005	69.2
Prior Computing Experience	0.405	10.1
Sex	0.539	5.6
Age	0.684	2.5
Corrected Model	0.042	71.7

**Table 8.3** Univariate Analysis of Variance showing the importance of selected variables measured from the Hypertext2 group, as prediction of Task 1 performance.

8.3.2 Task 2: Open Questions

Following a similar format to Section 7.3.2 from the first experiment, this section starts by displaying a boxplot of Task 2 performance for all experimental groups. As with Task 1, the median of the Hypertext2 group was higher than the medians of Book1 and Hypertext1.



**Figure 8.2** Boxplots of performance on Task 2 for the first experiment (Book1 and Hypertext1) compared with the second experiment (Hypertext2).

Univariate analysis of variance was again used to determine which variables could predict task performance. The first analysis involved a model incorporating sex, experimental group, mean academic performance and age from the Hypertext1 and Hypertext2 groups. The only variable found to approach the standard 95% significance level was sex.

Variable	Significance	Effect
Sex	0.055	11.7
Exprimental Group (Hypertext1/Hypertext2)	0.194	5.6
Mean Academic Performance	0.673	0.6
Age	0.838	0.1
Corrected Model	0.155	22.5

**Table 8.4** Univariate Analysis of Variance showing the importance of selected variables measured from the Hypertext1 and Hypertext2 groups, as prediction of Task 2 performance.

A second univariate analysis of variance using data from the combined Book1 and Hypertext2 groups found that only mean academic performance could predict a

significant amount (11.1%) of Task 2 performance ( $p=0.039$ ). The experimental group itself was not found to be a significant factor.

Variable	Significance	Effect
Mean Academic Performance	0.039	11.1
Sex	0.120	6.4
Age	0.285	3.1
Exprimental Group (Book1/Hypertext2)	0.327	2.6
Corrected Model	0.140	19.4

**Table 8.5** Univariate Analysis of Variance showing the importance of selected variables measured from the Book1 and Hypertext2 groups, as prediction of Task 2 performance.

A third univariate analysis of variance was used to perform an intra-group analysis of the Hypertext2 group. No variables, including prior computing experience, reached the standard level of statistical significance.

Variable	Significance	Effect
Mean Academic Performance	0.067	35.9
Sex	0.208	19.0
Prior Computing Experience	0.426	8.1
Age	0.928	0.1
Corrected Model	0.317	41.2

**Table 8.6** Univariate Analysis of Variance showing the importance of selected variables measured from the Hypertext2 group, as prediction of Task 2 performance.

8.3.3 Questionnaire

To permit direct comparisons to be made, the questionnaire from Experiment 1 was re-used in Experiment 2. Of the 14 hypertext subjects who participated, only one did not complete a questionnaire. Some of the more important findings are reported below:

- A. All Hypertext subjects had previous experience of the World Wide Web, and only one subject had not used the Microsoft Help system before.
- B. Preference for paper was even stronger than in Experiment 1 with all 13 respondents responding that they would prefer to read from paper (Question 5).
- C. The number of subjects preferring to use a paper-based version of the book when learning future topics (Question 12) was 69%, while 31% stated that they would be happy using either medium. Unlike the first experiment, no subjects responded that they would definitely prefer to use the hypertext version of the book.
- D. No subject reported experiencing 'many' problems getting to any pages/nodes (Question 7). In the first experiment 23% of the Hypertext subjects reported such difficulties. Seventy seven percent reported a few difficulties and 23% reported having no difficulties navigating to the desired nodes.
- E. In general, subjects reported the same advantages for hypertext when responding to Question 10. However, in addition to issues concerning speed, enjoyment and quick searching, subjects also reported that it was easier to call up illustrations and references. Also, the advantage of multiple windows which could display information simultaneously was reported by one subject. Again, all the disadvantages of hypertext discussed in Section 4 were also highlighted by subjects in the second experiment. Eight subjects commented that they found reading from the screen visually stressful, and two stated that they found it hard to concentrate for long periods in front of the screen. Added to these problems, three hypertext users reported that it was difficult to take notes while reading from the screen. One suggested that the keyboard was in the way.

## 8.4 Discussion

### 8.4.1 Effect of Training on Task Performance

#### *Task 1 performance differences*

The mean score of subjects assigned to Hypertext2 was 47.9% higher than the score of subjects assigned to Hypertext1. Taking into account the significantly higher mean academic performance of subjects in Hypertext2, using a univariate analysis of variance, it was found that the group (Hypertext1, Hypertext2) was a significant factor in predicting task score. This increase in Task 1 performance is certainly encouraging, as there were no significant differences between Hypertext2 and Book1. This finding is encouraging in that it suggests that subjects will not be unfairly disadvantaged when learning multidisciplinary subjects using hypertext. However, it is somewhat disappointing that hypertext was not actually faster than the book like Lehto, Zhu and Carpenter (1995) found.

Two possible explanations can be used to account for the significant improvement between Hypertext1 and Hypertext2. The first is that the hypothesis stated at the end of the first experiment was correct and a learning effect was observed. Hypertext subjects in the first experiment became familiar with the medium as a result of Task 1 and so Task 2 performance reflected their greater experience. Thus, using a separate group of experienced users in the second experiment, Task 1 performance was much higher since they did not have to learn how to use the hypertext system, but this advantage disappeared compared with the first cohort when completing Task 2. A second possible reason for this difference in performance is not due to a learning effect but instead caused by various properties of the task. For example, Task 1 required intensive hypertext interaction and minimal cognitive processing of the information once found, whereas Task 2 was almost the complete opposite, significant processing of information with less interaction and more detailed reading. It is therefore reasonable to hypothesize that the performance of hypertext subjects increased more on Task 1 because interaction



with the system was the limiting factor. Because the second experiment used more experienced hypertext users who were more efficient in terms of their interaction, they were able to answer more questions in the same period of time. However, subjects were required to perform more reading to answer the questions in the second task. Thus, the limiting factor was not navigational speed but instead cognitive processing speed and ability.

As reported in Section 8.3.2, in addition to Hypertext2 subjects answering significantly more questions than Hypertext1 subjects, their accuracy was higher as well. This was quite unexpected since the accuracy of Hypertext1 and Book1 was so similar, roughly 77% for each group. However, the mean accuracy of subjects in the Hypertext2 group was 83.3%, significantly higher than both Book1 and Hypertext1 groups. As already stated earlier, a Pearson correlation showed a positive relationship between mean academic performance and accuracy approaching the 95% confidence. This finding is encouraging for educationalists interested in utilising hypertext further since it suggests that the skills/abilities/styles that contribute towards higher marks using traditional learning materials can also transfer to higher accuracy rates when using hypertext. The challenge now is to decompose mean academic performance on a course into the important components in terms of mental ability, cognitive style and other individual differences. Once this is complete, a detailed analysis linking these attributes to hypertext use should begin. Where there is a large degree of overlap between ‘traditional’ learning skills and the skills required to use hypertext effectively, little extra training will be required, but where there is little overlap educators will need to include hypertext training in the curriculum.

### *Task 2 performance differences*

Although the Task 2 score of subjects assigned to the Hypertext2 increased 31.2% from that of subjects assigned to Hypertext1, this difference, taking into account other factors such as mean academic performance, was not found to be significant. While somewhat disappointing, the results were not unexpected. Mayes, Kibby and Anderson (1990b)



suggest that while learners are navigating through material which has been structured by other people, there is no reason why learning from hypertext should be any more effective than alternative forms of instruction. Also, as discussed earlier in Section 4.2.2, Clark (1994) asserts that when all extraneous variables are controlled, different media are often very similar in the learning effect they produce. Although he does acknowledge that ‘non-learning’ effects such as differences in time/place of access and cost can be important to educationalists. Using Clark’s position as a base, it seems unlikely that hypertext will have any significant impact on advanced knowledge acquisition and application until there is a corresponding change in methods, possibly through the use of constructive hypertext, as will be discussed in Section 9.2.2. However, the simple dichotomy between Clark’s *delivery technologies* and *design technologies* may not be as clear cut as some might believe. For example, Lemke (1993) discussing hypermedia states: “This simple quantitative change in ease of operation, however, can lead to profound changes: in scholarly communication, interactions between teachers and students, the skills of authorship, and in the very paradigm of learning itself.” If such an assertion is true then the timescales are likely to be medium to long-term. The Networked Learning Environment which the author has worked on for nearly two years, since conducting this research, is only just starting to facilitate quantifiable changes in the way in which the curriculum is delivered. However, like the current research, the switch from paper-based media to electronic media has yet to translate into any noticeable learning effect advantages.

### ***Reduction in Task performance ratio***

Not only did Hypertext2 subjects perform significantly better than Hypertext1 subjects on Task 1, but also their performance variance ratio fell from 4.2:1 to 2.1:1. The reason behind this smaller ratio was in the substantially better performance of the poorer hypertext subjects. The poorest Hypertext1 subject scored 5.0, whereas the poorest Hypertext2 subject scored 11.5. However, what is interesting is that the best performers only improved from 21.0 in the first experiment to 24.5 in Experiment 2. Given that subjects were only permitted 40 minutes to complete Task 1, the current results could

represent a ceiling effect in the number of questions answerable in the time. It would be interesting to conduct further experiments using the same hypertext system and Task 1 questions but not impose any time restrictions. In addition, it must be stressed that only 14 subjects were used in the second experiment, thus the statistical power of any findings is weak.

Interestingly, the ratio of Task 2 performance actually widened slightly for this second experiment. The poorest performer still scored 3.0, while the highest score increased by one to 21.0. Such a finding suggests that familiarity with Hypertext does little to improve Task 2 performance.

Although the performance ratio decreased only for the simpler Task 1 questions, the results are still encouraging when considering Duderstadt's (1997) vision of education for *everyone*.

### ***Effect of Computing Experience on Performance***

One of the important findings from the first experiment was that there appeared to be a trend towards subjects with longer prior computing experience performing better on Task 1. After providing Hypertext2 subjects with training and familiarisation time, it was important to determine whether prior computing experience was still an important predictor of Task 1 performance. Univariate analysis of variance confirmed that prior computing experience was no longer an important factor in either Task 1 or Task 2 performance.

While it is not possible to tell whether the better performance of Hypertext2, compared with Hypertext1, resulted from additional training, more familiarisation or from more experience with the underlying operating system, in the long term it does not really matter that this question remains unanswered. The important issue was to try to evaluate predicted future hypertext performance with existing book performance. While it is difficult to predict and extrapolate performance, it certainly makes sense to try to remove any confounding effects such as lack of practice with hypertext. Encouraging as

the current findings may be, it must be remembered that the subjects assigned to Hypertext1 and Hypertext2 were selected from two separate populations. The subjects selected for the second experiment were approached a few weeks later into the semester than those subjects in the first experiment were. Thus, it is conceivable that the Hypertext2 subjects had a greater workload and so only the more highly motivated and keen individuals volunteered for the experiment. Certainly, the question remains, are those subjects who participated in the second experiment similar to those who did not? While analysis of variance accommodates significant differences in measured variables, as discussed the experiments did not attempt to measure the effect of motivation.

#### 8.4.2 Questionnaire Findings

In total, eight subjects out of the 13 respondents, indicated in various ways that they found reading from screen problematic. This ranged from visual fatigue and too much glare to problems of concentration while studying online. A difference between Experiment 1 and Experiment 2 was that the latter employed 15" monitors, whereas the original study used larger 17" monitors. To compensate for this change in size, the screen resolution was changed from 1152 x 862 pixels to 1024 x 768 pixels. As mentioned earlier, the lower resolution coupled with the smaller visual display area resulted in the two different sets of monitors both displaying a resolution of approximately 90dpi. The effect of this should have been that subjects in both experiments viewed text and graphics of the same physical size. What could have contributed to the higher number of adverse comments about the smaller monitors was the smaller desktop area in which to re-size and position windows. With the Hypertext employing a number of 'secondary' windows (see Figure 6.7), a larger desktop would ease the user's burden of managing windows and would require less vertical scrolling since each window could display longer lines of text per line. The finding that users had more problems with the 15" monitors with smaller resolutions is useful since this size of monitor is still frequently used<sup>23</sup>. These negative attitudes towards smaller monitors

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<sup>23</sup> Frequently 800x600 pixel resolutions or lower are used with 15" monitor sizes, not the 1024x768 employed by the current research.

could also be associated with the lower percentage of subjects indicating that they would be willing to use hypertext for learning future topics. Some of the more illuminating answers given to this question (Question 12) as to why they would prefer learning future topics by book instead of hypertext were:

- **“I think it is partly because of what I am used to, and because it is real.”**

This indicates that interaction has not been fully internalised and automated; it is cognitively easier to operate the book. It is interesting that this subject implies that the hypertext is in some way unreal. This is probably because the two dimensional interface through which the hypertext is controlled does not seem as transparent or as powerful as the tactile feel and manipulation of a tangible physical paper book.

- **“Difficult to be open minded when you have learned from books for so long.”**

Suggests an important social consideration that applies to any new technology, resistance to change. As Cohen (1993) states, “... rejection of electronic publishing is more often than not based on the rather vague feeling that the printed book is an indispensable element in our society and that it has been with us too long to be easily displaced.” Often for new technology to be accepted, its users must perceive certain advantages that are unattainable using existing solutions. Experience with students using the Networked Learning Environment at the University of Nottingham confirms this: users are very keen on interactive features but often see little point in simple replication of text and graphics from traditional paper sources.

- **“As you are not spending time navigating around the system, it is easier to absorb information.”**

The transparency of the book interface is again highlighted by this comment. It appears that currently hypertext browsing is still a more conscious effort than reading a book and thus there is less cognitive ‘bandwidth’ with which to process the information. This is consistent with Mayes, Kibby, and Anderson’s, (1990b) comments that subjects either learned how to navigate the hypertext or learned the

content, but not both together, at least initially.

- **“I like the way a book is laid out and easier to understand which sections you have covered.”**

Several subjects indicated that they found it harder to appreciate their current location within the hypertext. However, the issue about book layout is interesting. Because of the limitations of current screen resolution, text is often scrolled vertically, whereas in a book multiple columns are frequently employed. Also, a larger area of material is visible on two facing paper-pages than typically available within a scrollable window.

In addition to the above reasons for reluctance to use hypertext in the future, four subjects commented that they *would* use similar hypertext systems to find specific pieces of information (reference tasks), whereas they would prefer books for more general study periods and revision. Such a finding, if it holds more widely, suggests that an ideal textbook might be one which is published in traditional paper-format but which comes with a CD-ROM containing the same text but in hypertext format. While this might appear to be duplicated effort, the cost of such publishing would not be substantially higher than normal costs. For example, the price of a CD-ROM disk is a matter of pence in bulk, and the speed with which hypertexts can be created from ‘standard’ text is fast using systems such as Adobe Acrobat. In a study investigating the use of hypertext to support the reading of building application documents, Kumbruck (1998) similarly recommends that such documents should be available in two formats: linear paper format and hypertext document. It was found that the linear paper format was preferred during an initial detailed reading of the building application document, whereas the hypertext supported the re-reading of specific sections better than paper. Thus, Kumbruck concludes that paper and hypertext have complementary functionality.

An issue only briefly raised by a few subjects in the first experiment concerned various environmental problems. Subjects in Experiment 2 reported that they found the

computer lab noisy and several highlighted a problem of taking notes while working at the computer. The issue of noise was unexpected since during all experiments a policy of no talking was enforced. However, in a computer lab with many computers, there is general background fan noise together with a more noticeable foreground typing noise. It could be that individuals who were concentrating hard on a difficult part of the hypertext were consciously aware of noise made by other subjects' typing. If this was the case, and it is suggested in Section 9.2.2 that further research is needed to clarify the situation, human-factors specialists and educational technologists will have to evaluate carefully any audio-based technologies (i.e. multimedia environments and voice recognition). Taking notes while using hypertext was found by many subjects to be problematic as well. Although not all subjects stated the root cause of this problem, one individual did state that this was because the keyboard was in the way. In most computer labs, the amount of unused flat desk space is relatively small. Bulky monitors, tower systems, keyboards and mouse-mats all impinge on this important space. Again, it is recommended that future workplace research be conducted to enhance the acceptability of using hypertext environments.

Several researchers have quoted serendipitous discovery as an advantage of hypertext, however one subject stated: "physical action of flicking through books often reveals info not found through index – this is missing on Hypertext." The inability to flick through the nodes of in the hypertext was also reported by subjects from Experiment 1 as well.

A related issue, concerning navigation, was the complaint by some subjects about not always knowing where they were within the hypertext system. It appears that the ease of hypertext linking, so often cited as an advantage, may in fact be partly responsible for many navigational problems. For example, to switch between chapters in a paper-based book the reader has to work out which page number to look up and then to physically manipulate the book until the right pages are opened. However, in the case of hypertext, all jumps, regardless of conceptual distance, are only a mere click away. The cues are also fewer in hypertext than in books.

## 8.5 Conclusions

It would appear from analysis of the performance of Hypertext subjects in both experiments, that training and familiarisation account for more variance in performance on tasks requiring intensive hypertext interaction (i.e. Task 1 – closed questions) than those tasks involving greater amounts of cognitive processing (i.e. Task 2 – open questions). Overall it may be concluded that the performance of subjects undertaking both open and closed-type tasks on multi-disciplinary knowledge domains are similar using printed books or online hypertexts once an appropriate level of skill with the software has been acquired. There is even evidence, together with previous studies reported in the literature, to suggest that Hypertext could be slightly faster when answering closed-type questions. However, a remaining question, which the current study could not address, concerns the long-term effects of prolonged exposure to hypertext. This issue will be discussed in further detail in the 'Future Work' section of the following chapter.

## 9. Conclusions

### 9.1 Summary of Research Contributions

The aim of the work reported in this thesis was to evaluate the usability of a paper-based book and a contemporary hypertext system containing the same multidisciplinary knowledge domain. Specifically, as initially stated in Section 5.2, the thesis presented four hypotheses:

1. Hypertext users will perform information retrieval tasks significantly faster than book users.
2. Hypertext users will not be more accurate than book users when engaged in information retrieval tasks.
3. The quality of essays in terms of concepts presented will not significantly differ between Book and Hypertext users.
4. Significant performance differences will not correlate with spatial ability or field dependence/wholist-analytic style in a modern hypertext system containing a variety of different navigational structures and functions.

To test these hypotheses an 800 page Human-Computer Interaction textbook was converted into hypertext system using MS WinHelp. Postgraduate student volunteers were then given two tasks to perform using either the original paper book or the hypertext version. Surprisingly, the first hypothesis regarding information retrieval speed proved untrue with Hypertext subjects actually performing significantly slower than the Book subjects. The second hypothesis, stating that information retrieval accuracy between the two media would be similar, proved true. The third hypothesis could not be rejected even though the higher scores of the Book subjects approached significance. In relationship to the fourth hypothesis, it was found that field dependence and spatial ability were not significantly related to the performance of subjects assigned to either Book or Hypertext. Surprisingly CSA (WA) was specifically related to the Task 2 performance of subjects assigned to the Book. Also, age was found to be a significant factor when both groups were analysed together on Task 1. Mean academic



performance was found to relate to Task 1 score for subjects assigned to the Hypertext condition. This suggests that the qualities associated with higher levels of performance on a postgraduate degree also transfer, to some extent, to higher levels of performance on a hypertext system.

One surprising finding to emerge from the first experiment was the trend for Hypertext performance to be related to prior computing experience, even though all subjects had been using computers for at least six months. A second experiment, using the same Book and Hypertext media as the first experiment, was conducted with students from the following cohort. Data from this second experiment confirmed that with more experience of the operating system and the specific hypertext system used, performance between Book and Hypertext subjects when performing information retrieval and short essay questions was similar.

The resulting contributions from this work are presented below under the following headings: hypertext construction, importance of the medium, importance of individual differences, importance of training/familiarisation and the acceptability of hypertext as an educational medium.

### **9.1.1 Hypertext construction**

This thesis makes a contribution to the growing body of knowledge about hypertext construction. As Meyrowitz (1991) comments, research is needed into hypertext systems at appropriate scales. Several of the early hypertext systems reported in the literature have as few as 40 nodes of information. It is easy to 'hand-craft' such a small number of nodes and to check that all links are working. However, one of the goals of the current research was to hypertextualise a book that was typical in size and complexity of the books used today in higher education. It was therefore decided to use the 800 page book *Human-Computer Interaction* by Preece *et al.* (1994). By splitting the book into its constituent logical sub-sections and adding pop-up nodes for glossary terms and

references the book was converted into 1,634 nodes and 3,295 links. The amount of time to manually check this large number of links would have been considerable. However, the MS Help Compiler Workshop allows hypertext documents to be created easily from correctly formatted RTF documents. When these source files are brought together and compiled into a single hypertext system the Help Compiler Workshop automatically checks the syntactic correctness of all links and reports any errors. In total, the time taken to format the digital source text of *Human Computer Interaction*, using MS Word, and to scan and add all the graphics took approximately 175 hours of work. This compares favourably with the 300 hours reported by Gilliver, Randall and Pok (1998) who converted 800 pages of existing word processed course documents into HTML format using MS Publisher. The Networked Learning Environment (NLE, 2000) achieves a similar saving of time when authoring large numbers of nodes by automatically controlling the insertion of links. One programmer is all that is required to manage over 50 courses requiring in total 26,000 database records. As hypertext matures from first generation prototypes into more mature second and third generation products, information about which authoring environments are most efficient from both an initial creation time and subsequent maintenance perspective will become important.

### 9.1.2 Importance of the Medium

As discussed in Section 4.2.2, there has been a vigorous debate surrounding the question of whether differences in the educational performance of a group of individuals can be attributed to characteristics of the educational medium being used. On the one hand, Ullmer (1994) argues that studies that try to mirror methods and content as closely as possible will never uncover the true potential of a medium, whereas on the other, Clark (1994) argues that any differences in performance resulting from the former type of media experiment would be due to the differences in method and content employed and not the medium itself. Other studies, for example Buchanan (2000), report significant performance differences in students who use a particular medium compared with students who had *not* used the medium. This type of comparison appears to be the

weakest type of media comparison design to draw conclusions from. The position adopted by the research reported in this thesis was to use similar content material between both treatments so that any differences in subjects' performances might more confidently be attributed to characteristics of the presentation media (book, hypertext). While it risks the problem that Ullmer outlines of not exploring the true potential of a medium, in this case hypertext, it is representative of the large number of straight book/document into hypertext conversions that are currently taking place throughout higher education. Although the research reported in this thesis did find a significant difference in student achievement using these two alternative media, it would appear from the second experiment, reported in Chapter 8, that this was most likely due to unfamiliarity with the hypertext experimental condition. Certainly the results from the second experiment show no clear significant advantages for either book or hypertext when supporting either information retrieval or more open-ended style questions. This appears to support Clark's (1994) argument since, after all, the hypertext did not possess any specific *design technologies*, it simply utilised the same method and content that the book version employed. Where hypertext does show an advantage, although this cannot really be fully evaluated in controlled laboratory conditions, is in its role as *delivery technology*. Here, as is the main motivation for the Networked Learning Environment project, hypertext is used to overcome the economic, geographic, physical, chronological and otherwise practical limitations of books.

### 9.1.3 Importance of Individual Differences

In addition to the overall performance of subjects on two different media, this thesis contributes findings to the field of educational psychology by seeking a greater understanding of the importance of individual differences. With such a large number of different mental abilities, cognitive styles, personality traits and other factors on which individuals differ reported in the literature it is difficult for educationalists to draw clear conclusions. This thesis attempted, by using a small number of specific measures of individual differences with a modern hypertext, to provide some insights. Unfortunately

all we can say from the current research is that further work in this area is still needed. For example, spatial ability was not found to be related to performance with the hypertext system. This, as discussed earlier, is at odds with the findings of several previous hypertext studies. In general, data from the current work reaffirms the importance of individual differences but shows that the relationship between these differences and task and medium is complex. Unfortunately this complexity hinders the creation of guidelines and recommendations with which to aid future hypertext design. One finding that is encouraging is the importance of mean academic performance with Book1 and Hypertext2 on the first task and Hypertext1 on the second task. In the subjects tested here, it seems that the characteristics which enabled them to excel using traditional learning materials also transfer, to a certain extent, into successful performance using hypertext. The absence of any correlations between spatial ability and cognitive styles and either medium, apart from WA and Task 2 performance with Book1 subjects, is potentially quite a useful findings for educationalists who do not normally measure such differences.

#### **9.1.4 Importance of Training/Familiarisation**

The research reported in this thesis reaffirms the importance of users learning how to use hypertext as well as learning from hypertext. All subjects in the first had at least six months experience of computers and all had used one or more hypertext systems prior to the experiments. However, this level of familiarity with hypertext was not sufficient to interact with the text as fast as subjects using the paper version. Investigating this phenomenon with a second experiment, it would now appear that actual familiarity with the underlying operating system and hypertext system are required for 'normal' real-world performance levels to be achieved. It is argued here that even though subjects from the first experiment knew how to interact with operating systems and hypertexts in general, the cognitive load imposed on them trying to perform tasks with new instances of such environments resulted in their overall poorer performance compared to the Book subjects. As a result it is recommended that any students required to use hypertext

learning environments be instructed in the specifics of the systems used within their institution as soon as possible before starting any assessments based on such online studying.

### **9.1.5 Acceptability of Hypertext as educational medium**

Although academic performance is of primary interest to educationalists, many other factors contribute to the practical acceptability of a certain educational technique with students. As was discussed in Section 4.6.4, printed text and electronic text differ in several ways. Factors such as availability and ease of annotation, movement within a text, layout and reading speed can affect the acceptability of one medium compared with another. Although the hypertext used in the research reported here utilised high resolution displays (1152x852 and 1024x768), large sans-serif fonts similar to the typeface of the book, participants indicated in the questionnaire that several problems remain. Given the rapid evolution of computer hardware, the finding, as reported in Section 7.3.4, that most individuals would prefer to read from paper (72%) and that most would prefer to learn from paper books (55%) was somewhat unexpected. This shows that although several of the software features, such as hypertext links, bookmarks and clipboard support, were enjoyed by most subjects, ultimate acceptability relies upon several factors outside the hypertext software system itself. In the publishing industry a large amount of work involves typographical and jacket design so that the resulting book or journal contains the properties and image that the target audience expect and want. Results from both experiments in the current research suggest that usability appears adequate but some acceptability problems remain. Experience on the Networked Learning Environment found that the cost of laser printing in a university can adversely affect student opinions about a hypertext system. However, in this case often a university-wide policy is taken which individual lecturers can do little about. Future 'e-learning' strategies should consider all of these wider acceptability issues rather than, as is too often the case, just analysing the hardware and operating system requirements necessary to run a particular hypertext system.

## 9.2 Directions for Further Research

Given that the performance of the Hypertext subjects in Experiment 2 was not significantly different from that of the Book subjects in Experiment 1 it is reasonable to suggest that hypertext can support the acquisition of advanced multi-disciplinary knowledge domains, such as Human-Computer Interaction. However, there is insufficient evidence to whole-heartedly recommend hypertext as an instructional medium. Instead, initially at least, further testing using larger numbers of subjects and with alternative domains is recommended. The time constraints of subjects involved in the current research limited the number who participated. Thus, from a statistical perspective re-testing with larger samples would be beneficial. Following this, in the medium to long term, research should concentrate on 1) establishing more precisely how individual differences influence task performance, and 2) the establishment of longitudinal field studies to investigate long term learning effects of exposure to hypertext. Although, findings from the questionnaire used in the current research confirm that there are still navigational problems and that users find reading from screens more stressful than paper, there is much research already addressing these problems. It is thus assumed that it is only a matter of time before these remaining 'system-level' problems will be overcome. However, the wider implications of hypertext use, which will be discussed in more detail below, are not well understood.

### 9.2.1 Individual Differences Research

As reported in Section 3.4, there are a large number of measures of cognitive style, several of which appear to measure very similar styles. To make cognitive style measuring easier, Riding and Cheema (1991) proposed a rationalisation of nine 'separate' styles into two orthogonal stylistic 'dimensions'. One of these dimensions, labelled 'Wholist-Analytic', was claimed to measure a similar style to field dependence (as measured by Embedded Figures Test, Group Embedded Figures Test, etc.). However, a Pearson correlation between the Group Embedded Figures Test (GEFT)

scores of 59 subjects and their Wholist-Analytic (W-A) scores revealed no significant relationship. Thus, it would appear that these two measures are in fact recording different things. Further research is needed to establish exactly why two allegedly similar tests produce non-significant correlations.

Mean academic performance was found to be a significant factor in predicting the performance of Book1 and Hypertext2 subjects on both tasks. While it intuitively makes sense that individuals who perform better academically should perform better in experiments of this type, it does little to inform the redesign of either medium. Although there is a general gulf in HCI between problems identified in usability testing and the clear formulation of an improved design, there are tools which can facilitate the bridging of much of this gulf. The recording of software log files is one such tool. The use of such files would enable educational researchers to determine why individuals with higher mean academic performance were able to perform better; was it just that they performed faster, or were there significant differences in the nature of their interaction?

### **9.2.2 Virtual Learning Environments**

The experiments reported in this thesis utilised hypertext representing a hyperspace of fixed size and well defined boundaries and a single user interface. Data from two experiments reported in Chapters 7 and 8 suggest that the performance of subjects using such a hypertext was statistically similar to those using a book on two separate tasks. However, the use of a hypertext in this context is as primary courseware during the conceptualisation phase of Mayes and Fowler's (1999) learning cycle (see Section 4.5.6). Real world learning experiences will require multiple information sources during this conceptualisation phase, not just one single 800 page book, and will also require adequate support for the other two stages of construction and dialogue. As a result, this section discusses a number of specific avenues for future work, all of which would contribute to the development of course or faculty-wide Virtual Learning Environments (VLEs).

***Longitudinal research***

Laboratory-based evaluations are useful settings to quickly evaluate carefully selected variables associated with experimental conditions, however, by controlling extraneous factors, ecological validity may be compromised (Kellogg, 1995). Data and resulting conclusions are often constrained by the quality of the original research questions. Also, Ullmer (1994) lucidly argues by way of an analogy that if nutrition scientists limited their studies to food intake from single servings then they would probably conclude that food does not cause cancer. However, by longitudinal monitoring of the growth of cancerous cells or how obesity may trigger diabetes, researchers can more accurately predict how diet influences and affects common diseases. One technique to achieve similar research in the field of hypertext is to use field-based techniques such as questionnaires, interviewing or ethnographic observation.

The problem with educational longitudinal studies is that certain ethical issues are raised. For example, where it is perfectly acceptable to have two or more experimental groups who are likely to differ on performance outcomes, having similar groups of students studying over a year or more and being significantly different is not acceptable. Therefore, unless some sort of study was set up whereby students participated in two different conditions during the research period in a cross over design, the research would be limited to one condition. However, with only a single condition it becomes impossible to conduct any sort of relative comparisons with alternative conditions as was done in the current thesis. This is the problem affecting the institutions involved in the TLTP3-86 project. In this project a VLE called the Networked Learning Environment (NLE, 2000) was constructed to create a digital representation of the curriculum. However, unlike the current research that 'translated' the material from the printed book into WinHelp, the NLE project, where possible, sought to take advantage of the new possibilities provided by online learning. Thus, even if a direct comparison was possible between the NLE and another method of learning, the study would be open to the methodological limitations outlined by Clark (1994). Here he warns that any gains in learning performance would be attributable to the methods employed and not any differences in the learning environments (media) used.



To avoid these *comparative* evaluation problems, *relative* evaluation techniques within a longitudinal project could be used. For example, through careful auditing the cost of such systems could be evaluated (reductions in photocopying, additional time preparing electronic materials, etc.) and class exam performance monitored each year or at the end of each semester. Changes in the attitudes of both staff and students to online learning could as well be monitored by annual questionnaires, interviews or focus groups (Lindgaard, 1994). Modifications and improvements to a system could then be made in the light of these longitudinal trends. However, it has been the experience of the NLE (2000) that system acceptability and usability are not absolute, but instead change over time as users bring expectations from other systems (see Section 7.4.3) and the capabilities of the technology changes. Thus, the data resulting from a semesterly or yearly evaluation would not be compared directly with previous years, but instead used as a measure for the change within that period. An analogy would be with the growth rings on a tree. The rings towards the outside of a tree are always larger, in terms of circumference, than the inner rings, however, it is the thickness of each ring that indicates the amount of growth for a particular year. So too will the 'circumference' of user's expectations increase each year as the technology evolves, but the relative changes in system usability can still be displayed as shrinking or increasing rings for that semester or year.

### ***Complete Learning Cycle support***

As already stated, the hypertext used in this thesis and indeed most hypertext research is primary courseware supporting the conceptualisation phase of Mayes and Fowler's (1999) learning cycle. Most educational hypertext systems currently in use support this stage in the learning cycle together with a number of newsgroups, discussion boards, chat and email that comprise tertiary courseware support for the dialogue stage. However, in comparison, much less research has been given to investigating the use of hypertext as secondary courseware able to support the construction phase of the learning cycle. Hypertext has been suggested as a suitable medium to support constructivistic theories of learning (Gill & Wright, 1994; Greening, 1998) but the theory's emphasis on

the investigation of domains from multiple perspectives, the use of authentic tasks and settings, and the active participation of students in the learning process, tends to minimise the amount of constructivistic research that can be achieved with limited experimental time.

Cunningham, Duffy and Knuth (1993) posit that paper-based books are not suited to constructivistic learning principles. Instead, they propose the use of electronic learning environments which allow students to create their own textbooks. "That is, they will be assembling information from a variety of sources, including their own thoughts and views, to present their understanding of an issue." (p. 31). However, the majority of hypertext systems in current use employ fixed, author generated links. While this is thought to be useful, since it allows novices to examine the knowledge structures of experts, in practice such systems may have limited relevance for learners. Because the schema between novices and experts differ significantly, it can be difficult for a beginner to know where to start in a new domain or what to look for. Jonassen (1991) suggests that personal relevance can be increased by allowing users to modify content and links within the hypertext. However, in a project specifically studying the effect of user-generated links, Harmon and Dinsmore (1992) found that some subjects formed inaccurate understandings. For example, they state:

"One subject left the study thinking Camp David was a concentration camp in World War II. Because of this finding, we believe that we can only say that these systems allow learners to construct their own world views, and there is no evidence that these newly constructed views will be consistent with the norm."

Although such a finding is concerning, it must be remembered that misconceptions can also occur using traditional books. It is important that additional research is conducted into constructivistic hypertext. One question which needs to be answered is, 'Can a hypertext environment be created which permits a high degree of learner autonomy, but at the same time provides enough scaffolding to limit the misconceptions that Harmon and Dinsmore (1992) describe?' While error-free learning is not advocated – indeed the

process of discovering and rectifying conceptual misunderstandings is highly valuable – procedures to encourage the detection and resolution of such problems would be welcome. Issues to be addressed in hypertext systems which permit users to construct their own material include:

1. Most importantly, and a recommendation also made by Harmon and Dinsmore (1992), is the need for research to investigate how editable versus uneditable hypertext systems impact on learning. Since such systems are believed to have the potential to support constructivistic learning, future research should employ real-world complex subject matter in line with the principles of constructivism.
2. What are the trade-offs between private and public alterations made to the hyperspace (Burbules and Callister, 1996)? For example, subjects could be permitted to view the annotations, new links and additional nodes of other users (similar to communal postings in an Internet newsgroup), or changes could be limited so that the only ones available are those which the current user made (current situation with MS Help annotations).
3. At a system level, it is important to find out what types of links users need to make. A number of researchers have proposed different numbers of link types, but do these contribute to the learning experience or are generic links equally useful?

If further research into customisable hypertext is successful then it will permit the use of systems similar to the Memex proposed by Bush (1945). Although the Memex was exceedingly efficient in terms of storage, its main advantage, Bush claimed, was its ability to overcome the limitations and supplement the user's own mind. Unless users can actually change the content of an existing hypertext, or construct their own, the information is unlikely to match their own knowledge structures to any greater extent than books and thus be no more efficient.

***HyperCurricula support***

Related to the above notion of constructivistic hypertext, is the idea of forming digital libraries of interconnected hypertext systems, or 'hyperlibraries'. Theories of constructivism hold that learning should take place in the context of realistic scenarios which exhibit the natural complexity of real-world problems. The creation of such environments will clearly involve a large range of different inter-related hypertexts. However, moving from small lab-based scales to 'real-world' scales often produces unforeseen secondary effects. For example, Patel (1998, p. 8) discusses the effect of IT on the demand for print resources:

"...the rapid growth of electronic information has had 'no impact' on the demand for traditional research resources. If anything, IT systems have stimulated greater use of print-based material by providing researchers with sophisticated tools for tracking printed and archival material that was previously difficult to find. Rather than it being a case of digital versus print in institutions, the reality is more the 'hybrid' library in which the use of print and computer is inter-related."

Kurzweil (1992) raises a similar point – far from IT resulting in the much predicted paperless office, such technology has actually substantially increased the amount of paper used. Kurzweil (1992) quotes figures showing the 850 billion sheets of paper used by American businesses in 1981 increased to nearly 4,000 billion sheets by 1990. These two examples, together with many others not mentioned here, make it clear that current short-term lab-based hypertext evaluations can only start to scratch the surface of understanding the future impact of hypertext.

As already stated, if hypertext is to truly support constructivistic learning principles then it will have to cope with the multi-disciplinary, multi-document reading habits of current scholars. While it is indeed possible to open several 'individual' hypertexts at once for consultation, the real potential of this technology lies in its ability to facilitate faster and more convenient access to disparate texts. Such changes could affect the overall evolution of knowledge (Drexler, 1996). The Networked Learning Environment (NLE, 2000) project has already successfully adapted recommended reading lists to

include links to library OPAC systems. These links, when selected, use special scripts in the library system to go straight to the details of the required title, not simply the OPAC homepage. From this details page the user can obtain standard information such as what library the book is in, shelf mark and other relevant details together with a real-time display of the status of the book (on shelf, short loan, out on loan and due back at a certain date, etc). The goal of this active linking between the Networked Learning Environment and library systems is that one system adds extra value to the other in so far as the extra convenience of the information a click away is likely to increase the users' chance of using it (Aust *et al.*, 1993) (see Section 4.2.2). However, it has been the experience at the University of Nottingham that creating these synergistic links between various sub-systems is often difficult, not because of technical issues, but more due to various political/institutional issues. Although initial comments about the recommended reading list links have been positive, further research is necessary to understand the possible long-term effects of these small quantitative changes in speed of operation. Consider the scenario suggested by Burbules and Callister (1996, p. 27):

"For example, if I am drawn from a chance comment in the introduction of one text to a quotation, and from that to a biography of the speaker of the quote, and from that to an historical account of the era in which she spoke, I will be not only gaining new information, but relating these 'nodes' together in ways that may be entirely independent from the purposes of the original essay."

Currently, one of the considerations made when deciding what document to read is how accessible the document is. Is it better to spend a day obtaining the text, or will a similar title which sounds almost as good and is accessible in five minutes be better? Often there are many levels of accessibility ranging from a book already held by the reader to one requiring inter-library loan that could take several weeks. However, by employing hypertext technology it is not difficult to imagine a scenario in which all documents are equally accessible. But would such an utopian 'docuverse' enhance the possibility of serendipitous discovery, or in fact merely overwhelm the reader. Although not always the case, there is certainly a loose relationship between the quality of a publication and

its accessibility in paper format. For example, academic bookshops frequently stock multiple copies of a recommended textbook. Also, the more prestigious journals, which are held by many libraries, have rigorous refereeing processes which permit only high quality papers and articles to be accepted. But if all documents in a hyper-library are equally available, the user may need to spend additional time trying to ascertain the quality of the publication before deciding to utilise the information.

In order to be able to construct and utilise hyper-libraries, it is vital that open standards for hypertext interoperability be established. While this is more of a commercial problem rather than research oriented, it is nevertheless important. Barron (1995) discusses three important problems which can affect electronic documents: differences in fonts between publishing system and viewing system, problems with different national character sets, and problems with hypermedia links. The medical school timetable at the University of Nottingham is a good example of incompatible data formats that prevent efficient linking between systems. Timetable sessions are originally entered into a propriety MS Access database created internally within the medical school. Having fully populated all the sessions and resolved the conflicts some of this data is used to populate the central university timetabling system. Unfortunately this central database does not contain all the necessary fields to hold the data and is not able to handle the complexity of non-modular courses. These factors, coupled with the inability of MS Access to support large numbers of concurrent web requests, necessitates the need for a third MySQL database which holds identical data to the MS Access database but can successfully interface with the Networked Learning Environment. Although the three different databases work relatively well since the data is only changed radically once a year, it is easy to imagine a number of more frequently updated datasets where maintenance would become a large problem. Although the timetable represents a bad case of data duplication, part of it also represents efficient data storage. Using the web application development environment Zope, the Networked Learning Environment uses the one timetable database held in MySQL to render XHTML formatted data to desktop web browsers, HTML 3.2 data to PDA devices and

WML data to WAP mobile phones. Using dynamic scripts inside Zope enables the data to be held once in a generic format and then device-specific tags to be included just in time before being sent to the browser. When the W3C moved from HTML 4.0 to XHTML as their current recommendation, only a few scripts had to be changed, not all the content data.

Increasingly the World Wide Web is being used to 'abstract' above the operating system level to provide hypertext environments that are platform independent. Utilising open standards such as HTML and XML Internet, intranet and extranet systems can be created with appropriate firewalls to enable various systems to interoperate. For example, in medical education systems are being developed that bridge the divide between NHS and university sub-systems. However, although many systems are platform independent, additional problems such as authentication become increasingly important. A learning environment which requires students to log on to read the course aims and objectives, another sign on to enter the institutional library and then another authentication procedure to access say an electronic journal could start to cause usability problems especially if usernames/passwords are forgotten. In a survey of 21 UK Medical Schools, Cook (2001) found that out of 17 institutions who actually employ a VLE, only 10 had successfully linked their learning environment with student records systems and only 8 had linked their VLE with a library OPAC system. Reasons for these low figures included technical difficulties with data transfer and institutional politics. However, the new IMS (IMS, 2000) specification appears to be a fruitful way of encapsulating open-standards for information transfer between disparate systems. The commercial online assessment system *Perception* is IMS compatible allowing questions from any other institution using Perception, or indeed any other IMS compatible assessment system, to easily transfer data. Other commercial systems, such as BlackBoard, are signing up publishing houses to develop ready made content 'plug-ins' which can be purchased to populate the learning environment. However, without robust and widely-adopted open standards, some institutions may find that the VLE that they are using cannot support the materials that some of the publishers are selling.

Another reason for longitudinal research into hyperlibraries is to determine the costs involved. It would appear from the work reported in this thesis that hypertext creation is relatively inexpensive. Even in situations where the original text is not available in electronic format, the cost of conversion is not prohibitively expensive. On the Networked Learning Environment project, a 140 page book, for which the source was unavailable, was scanned and converted into XHTML in two weeks. This included optical-character recognition (OCR) of the text, some editing work of the images (over 300 graphics) and the creation of all necessary hypertext style sheets and navigational structures. However, the salary costs associated with this two week conversion are only the creation costs, as Kuny and Cleveland (1998) warn, there are additional costs. Just as many old books printed on acid paper currently require special maintenance and preservation, so too do electronic books. As new computer systems evolve with additional functionality, the format of their data files usually change also. Backwards compatibility is sometimes maintained a few format generations, but sooner or later there are no modern systems capable of reading the old data. Importantly, Kuny and Cleveland (1998, p. 110) point out that, "cost models for the regular 'refreshing' of electronic data have not been established." While it could be argued that if knowledge is evolving ever faster and there are so many new publications why would readers need access to older publications, but the recorded knowledge of society at any particular period in time is highly important to both sociologists and historians alike. Imagine a library system which did not contain any publications older than ten years. It has been the experience of the author on the Networked Learning Environment project that the timescales involved in the 'digital refresh' of existing electronic materials can be very short indeed. The author was involved in supervising the re-scanning of photographic slides used on one of the courses at the University of Nottingham Medical School. These slides had already been digitised approximately three years earlier but because of the more limited resolutions and colour depths available at that time the images had become unacceptable given the capabilities of modern computer equipment. However, the problem in this specific case was that unlike text that can be marked up in a



different formatting language relatively easily, the original digital images were bitmapped graphics that could not be improved. Thus, the new digital images had to be re-scanned using the original photographic slides, a process that probably took as long to complete as the first scanning session.

### *Adaptive Hypermedia*

This thesis has concentrated on evaluating a printed book with a digital representation of this document in hypertext format. Although the hypertext version supports certain features not possible using paper, for example searching and popup references, the material is essentially static. However, a new field, known as 'Adaptive Hypertext' is emerging which seeks to apply user-modeling and adaptive systems techniques to hypertext/hypermedia (Henze, 2000). The purpose of creating a user model is to allow a hypertext system to adapt to the specific needs of different users. Brusilovsky (1998) comments that one of the most popular application areas for adaptive hypertext is educational hypermedia. He argues that the knowledge held by a group of users can differ substantially, and, within a particular individual is subject to change. "The same page can be unclear for a novice and at the same time trivial and boring for an advanced learner." (Brusilovsky, 1998, p. 6). Having established an initial rationale for adaptation, Brusilovsky (1998) asks, what features can be changed. He argues that current systems can adapt to: 1) the user's *knowledge* of a particular domain, 2) the user's *goal* or *task*, 3) general *background* of the user including information such as profession and experience of work in areas related to the adaptive system, 4) the user's *experience* of the structure of the hyperspace, and 5) the *preferences* of the user. With these aspects in mind, Brusilovsky (1998) posits that there are two main types of adaptation that can be achieved: *adaptive presentation* and *adaptive navigation support*.

Adaptive presentation techniques discussed in the literature usually refer to adaptation based on user knowledge. The system adapts the hyperspace according to a model of the current user. Boyle and Encarnacion (1998) describe a system called *Metadoc* which classified users into four categories (novice, beginners, intermediates and experts) based on their current knowledge of Unix/AIX. The system used these stereotypes to control

how much information to display to the user. For example, explanation of concepts associated with lower levels of knowledge were suppressed for higher level users. In another study Höök (1997) found that users assigned to an adaptive hypertext system opened fewer nodes than users assigned to a non-adaptive system. Höök (1997) concludes that the system was useful in that it presented the most relevant information to the user. However, given that users in the adaptive system looked at fewer nodes, the opportunity for serendipity appears likely to be less than traditional hypertext systems. This could be useful in domains that encourage convergent outcomes, such as medicine, but of less use in fields which are divergent. As already mentioned, most studies have investigated adaptation based on a model of the user's knowledge. However, there is no reason why models based on cognitive style could not be created. A simplistic version could alternatively render graphical or textual information depending on whether the user was an imager or a verbaliser.

In addition to adaptive presentation, adaptive navigation support systems control the presentation of links to a user. This could be a 'next' or 'continue' link, sorting of links, link annotation, link disabling or map adaptation (De Bra, Brusilovsky & Houben, 1999). Mathé and Chen (1998) describe a system called HyperMan which is used by NASA Space Shuttle flight controllers to access large amounts of information. The system works by allowing users to mark parts of a document as interesting using user-defined concepts. Subsequent information retrieval is facilitated by the construction of dynamic results sets based on the users' personal concepts. Like adaptive presentation, there is no reason why various individual differences cannot be used to help adaptive navigation support systems. For example, an adaptive system responding to a low spatial ability stereotype could render linear node/link structures with 'next' and 'previous' buttons to minimise the spatial load. Conversely, if the system detects, either implicitly through actions or explicitly through a preference setting, that the user has high spatial ability then the system could present the information in hierarchical structures or even network topologies.

***Socio-cultural research***

Benyon, Crerar and Wilkinson (2001) suggest that there are three distinct factors which contribute to possible user *exclusion* from various systems. Initially a system must be *accessible* to a user, that is physically in terms of time and place and also operationally suitable for the user. Once a fundamental level of system accessibility has been achieved, *usability* or quality of interaction becomes important. This can be divided into several factors including number of errors made, subjective satisfaction, and time required to perform various tasks. In addition to sufficient accessibility and usability, for a system to be widely adopted it must have adequate *acceptability*. Contributing factors can include: convenience, cost, cultural mores, social habits, and perceived usefulness in context. As mentioned in Section 7.3.4 and Section 8.3.3, subjects assigned to the Hypertext document frequently cited full-text searching as a useful facility, but when asked to comment on using a similar learning environment for future topics, the majority of Hypertext subjects from both experiments expressed a preference for books. These findings, especially marked in the Hypertext2 group, suggest that there is a social problem of acceptance. The accessibility and usability of the hypertext system must have been sufficiently high since the performance of Hypertext2 subjects were not significantly different from Book1 subjects. However, over two thirds of Hypertext2 subjects would prefer to use books for future similar learning situations. Part of the reason why the acceptability of hypertext appears lower than books might be due to the wider environmental context in which the hypertext was used. For example, questionnaire responses indicated that several subjects found it difficult to take notes while using the hypertext, while others complained about the general noise in the lab. One subject specifically stated that note taking was difficult because the keyboard got in the way. With high numbers of computers in each lab the amount of flat desk space is limited. Ergonomics research is obviously necessary here to determine users' note taking behaviour and how best to support this. In the long-term it may not be necessary to take notes on paper, software notebooks and conceptual organizers may be used instead. Noise was another factor which was surprising, since no talking was permitted during all experiments. However, in a lab with several computers being used at once there is the noise of the fans, together with the sound of keyboard clicks. Trying to

understand a difficult concept in this type of environment is quite different from doing so in the silence of a library reading room. Again, more sustained field work is necessary to resolve these problems. With hindsight, it is not surprising to experience some environmental problems since the computer lab was used in a way that is traditionally supported by the library reading room (the environment used by the book subjects). A long-term question will be, is it better to update the computer labs/classrooms to deaden noise and facilitate easier note-taking, or is it simpler to modernise libraries to support new forms of reading. Research in this area must be pragmatic if costly errors are to be avoided. With the current change from a predominantly 'desktop' computing paradigm to a more network and mobile supported paradigm, future workplace ('studyplace') solutions must be sufficiently flexible to support these changing work practices. If not, universities run the risk of spending large sums of money on physical environments which will become inappropriate in the medium to long-term. Carver, Howard and Lane (1999, p. 37) report:

"Finally, students appear to use only those hypermedia tools available to them in their rooms. Tools that require the student to use a lab or special equipment are seldom used and poorly rated on average."

One of the limitations of the current study was the limited scale of the hypertext system used. Few organisational politics are encountered when a single researcher acts as sole developer on a system. However, new projects, such as the Networked Learning Environment, are constructing hypertextual curricula for medical schools involving many academic school from across the faculty. With up to one thousand associated academic staff there are many system acceptance issues. For example, once material is uploaded into an educational intranet the information is open to peer scrutiny. It is the experience of the author that some lecturers resist adopting these new electronic system because of such peer review and scrutiny, not because of the system usability. Peer review though is but one issue, further sociological research within academic institutions is required to determine the best way to maximise system acceptance and academic advantages.

### 9.3 A Glimpse of Futurity

"The brown and charred rags that hung from the sides of it [the gallery], I presently recognized as the decaying vestiges of books. They had long since dropped to pieces, and every semblance of print had left them. But here and there were warped boards and cracked metallic clasps that told the tale well enough. Had I been a literary man I might, perhaps, have moralized upon the futility of all ambition. But as it was, the thing that struck me with keenest force was the enormous waste of labour to which this sombre wilderness of rotting paper testified. At the time I will confess that I thought chiefly of the Philosophical Transactions and my own seventeen papers upon physical optics."

(Wells, 1995, p. 51)<sup>24</sup>

Having explored the educational literature, conducted a series of experiments and proposed a number of avenues for further work, it is interesting to speculate about what the future might bring. Doing so is extremely difficult, to do so accurately anyway, since each of the major societies listed by Robertson (1998), see Section 2.1, would be largely unrecognisable to an individual from a previous society. The latest information explosion, the transition from print to computers begun just over fifty years ago. However, as Robertson (1998) suggests, this revolution will be much larger and will occur faster than any previous revolution. "The difference between the twentieth and the twenty-first centuries may well be greater than the difference between the twentieth and the thirteenth (A.D. or B.C.)." (Robertson, 1998, p. 32). Similar sentiments are expressed by Nielsen: "In predicting the effect of technological changes, the two most common mistakes are to over-estimate the short-term changes and to under-estimate the long-term changes." (Nielsen, 2000, p. 348). If the difficulties of predicting the future are so great, the very point of such idle speculation could be questioned. However, its value is as a long-term frame of reference within which shorter-term research may be guided.

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<sup>24</sup> Original source: Wells, H. G. (1895) *The Time Machine*.

### 9.3.1 Dominant literary media changes

In analysing the current transition from print to digital form it is interesting to review the last major literary change from writing to print. As Jean (1987) writes:

"Nevertheless, printing did not immediately take the place of writing. Its progress depended on the solution of many difficult technical problems."

(Jean, 1987, p. 95)

The words *printing* and *writing* could be replaced with *hypertext* and *printing* respectively and the above quote would still remain relevant for society's current literary situation. Although the paperless office and bookless society have not yet arrived, Gaur (1984) argues that the position of print has changed fundamentally by the introduction of digital media. The relative importance of two main factors which support the ubiquitous nature of paper-based media, cost and convenience, are changing quickly in computer-dominated societies.

Computers, since their inception, have stored information. Initially this was limited to small amounts of numerical data and was very expensive to store. Just over fifty years later and large amounts of numerical, textual, graphical and audio information formats can easily be stored. As discussed in Section 2.1, the cost per megabyte of digital storage is likely to fall in 2001 below the cost of storing information in 'traditional' formats (paper, film, slide). When this price advantage for digital media occurs, stakeholders such as academic libraries will be under enormous economic pressure to adopt these new electronic systems simply to maintain effective coverage of their subject matter.

The second limiting factor affecting electronic documents is their convenience. Modern well typeset books are visually easy to read (high resolution, good contrast) and are portable (in limited numbers). Early hypertext systems, being computer-based, were effectively tied to bulky and often slow desktop computers. However, just as the rapid

advance in technology is reducing prices, so too will it improve the readability and the physical convenience of electronic documents. Although laptop computers in the year 2000 do not have the 500 to 1000 dpi resolution predicted by Kurzweil (1992), they can now rival the resolutions offered by expensive 17" monitors only a few years previously. Also, Microsoft has demonstrated working versions of its Reader software which utilises ClearType technology. ClearType in essence performs font anti-aliasing at the sub-pixel level by addressing the individual red, green and blue colour signals. The result, which currently can only be achieved on LCD screens, effectively triples the 'standard' resolution of the display. Microsoft is hoping that this new technology will encourage the development and adoption of electronic reading. It is working with 40 different companies to ensure compatible electronic book standards (Microsoft, 1999) and has signed a deal with the bookstore Barnes and Noble to create electronic 'eBook Superstores' (Microsoft, 2000).

### 9.3.2 The Internet

It is becoming increasingly clear that the Internet will be the dominant framework of protocols supporting the various electronic media mentioned in the previous section. Although the Internet has been used for academic research during the 1970s and 1980s, Baer (1998) argues that it has only been since the 1990s that it has been used seriously in undergraduate and graduate education. Many educational web sites have seen impressive growth in terms of the number of pages available and the amount of use by students. The Networked Learning Environment at the end of 2001, two and a half years after inception, had 1,600 uploaded resources<sup>25</sup> and over 1.3 million pages were accessed over the previous 12 months. But what has the practical effect on education been from the use of academic web sites and VLEs? Cook (2001) reports that evidence about the effect of Internet VLEs on teaching and learning is rather limited. However, he suggests that the impression he obtained from detailed interviews at 6 UK Medical Schools was that the Internet had not affected teaching and learning practice

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<sup>25</sup> Files (Word, PowerPoint, PDF, etc.) or Internet links.

significantly thus far. It is useful, though, to perhaps make a distinction, as suggested by Clark (1994), between *delivery technologies* and *design technologies*.

When considering the Internet from the perspective of 'delivery', its effect has, and will continue to be, very significant. It would appear that it is the Internet's use of open standards, such as the HTTP protocol, that has contributed to its success rather than its functionality as a hypertext system. After all even XHTML is quite poor when compared with some of the functionality available in other systems. What the open standards have allowed is a blurring of the sharp distinction between distance learning and traditional on-campus education (Baer, 1998). As already mentioned in Section 2.2, the circumstances in which students find themselves in is changing. Greater financial burdens and increasing pressures of lifelong learning are driving a need for more flexible forms of higher education. The results<sup>26</sup> from a questionnaire given to students of the Nottingham Networked Learning Environment in Spring 2001 found that they actually spent more time accessing this particular VLE from home (2.5 hrs/week) rather than on-campus (2.4 hrs/week). A second conceptual blurring that the Internet is encouraging lies between academia and industry. As Gomory (2001) notes, for the first time 'lifelong learning' can be more than just a phrase. He suggests that this is not only for those individuals wishing to learn but who cannot leave their jobs to do so, but also the phrase is relevant to those aspects of education that have never occurred in the classroom. For example, during 1998 all UK Medical Schools undertook a redesign of their curricula, in the light of a 1993 GMC report, which included a higher level of undergraduate teaching and learning conducted at hospitals and general practices remote from a central campus (Cook, 2001). While not distance learning in the traditional sense, medicine is a good example of a highly vocational field where cooperation between academia and industry is vital.

From a 'design' perspective the Internet has probably been less successful. Cook (2001) suggests that in many cases lecturers try to include materials which they use in their face-to-face teaching on the Internet without modification. At the University of

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<sup>26</sup> [http://www.nlc.nottingham.ac.uk/nlc/desktop/evaluation/nlc/students/report\\_2001](http://www.nlc.nottingham.ac.uk/nlc/desktop/evaluation/nlc/students/report_2001)



Newcastle, University of Nottingham and the University of Sheffield, lecturers can upload Word handouts and PowerPoint presentations using simple templates. While this undoubtedly is very convenient and saves time, reading a bulleted list of points in PowerPoint at home misses the verbal elaboration of the lecturer in the classroom. Baer (1998) argues that to take advantage of the web will require the assistance of multimedia experts during course design, a service few academic institutions today are able to provide.

In the long-term it is likely that the Internet will diversify into specific niches. To date most sites have used the simple generic node and link facilities provided by plain HTML. However, future sites are likely to use complex programming languages to achieve: e-commerce for buying goods and services online (e.g. Amazon), streaming capabilities for entertainment services (e.g. Napster), web-delivered applications (e.g. Microsoft) and education-specific support facilities. The educational uses, as already mentioned, have mainly been presentational – delivery type technology. However, more emphasis is likely in the area of design technologies which actively seek to improve performance and quality. The first area expected to be developed lies in the field of curriculum mapping (Howe, *personal communication*). Such a technique involves the creation of a hierarchy of high-level degree programme *outcomes* being linked to a number of course *aims* which in turn are achieved by fulfilling specific session *objectives*. These objectives are covered by a number of teaching/learning *sessions* (lecture, tutorial, practical, private study) and ultimately are assessed by some form of *assessment*. With the rapid developments in some fields, as mentioned in Section 2.1, it is becoming increasingly difficult to manage large curricula without IT support. Although such curriculum mapping tools do not have to be Internet-based, it is highly likely that they will be because they will be designed to integrate with the presentational aspects of VLEs that students use. The resulting VMLEs (Virtual Managed Learning Environments) will then allow staff to easily perform ‘what if’ questions whereby they can easily simulate the effect on objective assessment if, for example, an exam was dropped or a module replaced. A second area which is likely to receive more interest is

the monitoring of students' online browsing behaviour and the intelligent suggestion, through adaptive hypermedia, of further material to study. It is also likely that such systems will be linked to online formative assessment systems whereby, given a knowledge of what a student has already read, together with a breakdown of questions they have answered incorrectly, the system will present a dynamic and personalised 'remedial' revision plan.

### 9.3.3 Digital Synchronisation

A second future trend which is nearing completion, and which will greatly affect publishing and communications, is the switch from analogue information formats to digital. Following the digitisation of text using computers, pre-recorded audio music became available on Compact Disc, video can now be stored digitally on Digital Versatile Discs (DVDs) and live television and radio broadcast digitally. Although there is much hype and large profit margins for the early innovators, for the first time all the major communications media and formats will be digital. The advantage of this is that using a computer as a binary number cruncher, all these different formats can be seamlessly merged and manipulated. At the moment there are some well integrated multimedia systems available (especially the multimedia encyclopaedia and dictionaries). However, in the future it is not difficult to imagine a much more sophisticated integration which utilises hypertext as the main access paradigm. For example, a 'learning experience' could consist of allowing a student to study a film on video, switch to an online searchable version of the book, possibly the film script, then hear various tracks from the soundtrack and link to each artist's web site. While much of this vision appears quite possible currently, the real problem is the *synchronisation* of these multiple data streams. For example, if the video is paused at 1:24:56, which section of text from the book and script is relevant? Also, links need to be dynamic. For example, most modern soundtracks utilise tracks from several different artists. When the user switches from 'Chapter 4' to the soundtrack, which one will play? A list of static links to all the artists could be developed but this would require more screen real-estate

and impose a greater cognitive load on the user. Early examples of how this could work are available currently. For example, it is possible in DVD Video to switch from English language to French part way through a film without starting again at the beginning. Thus, the synchronisation mechanisms must already exist between the DVD audio and visual data streams. However, both data types are temporally based. Seamlessly linking between temporal and non-temporal formats will be much more difficult. A number of additional design issues are raised with greater media integration. For example, in temporal and non-visual data formats what is the most effective method of indicating hypertext link anchors? Should markers be indicated explicitly, or, as is the case with DVD Video, should the onus to follow a link be left up to the user who can select a function at any time from the remote control?

#### **9.3.4 Advances in Hardware**

On reading Conklin's (1987) review of hypertext together with Bush's (1945) Memex proposal, it is interesting to note the hardware used in these systems. The NLS workstation used by Engelbart, described by Conklin (1987), consisted of a monitor which could include television images and was controlled by new input devices: the mouse and chord keyboard. Although, the exact specifications of the Memex were never completed, the device possessed a number of levers and switches and, importantly, had multiple projection screens for viewing documents. A link created by displaying the two required documents in adjacent screens and then activating some sort of control. This is very different from the current method of inserting hypertext links. The source node is often displayed, but then the user has to focus on creating the link referring to the destination node by name. Using a Memex system, the user does not worry about the syntax or spelling of the link itself, all the user worries about is which two documents to associate. Since the commercial introduction of GUI-based operating systems with the Apple Macintosh in 1985, little change has occurred in the main personal-computer interaction paradigm. Clipboard functionality has been added, fonts shared by applications, and better support for multimedia file formats, however, the direct

manipulation system is still basically the same as the original Macintosh. The time is now ripe for research into new forms of interaction. Although, not directly reliant upon hardware, new devices will permit novel interaction possibilities. Signs of such new devices, although few and far between, are starting to emerge. For example, the new Millennium G400 graphics card developed by Matrox has a 'dual-head' function. The dual-head provides two d-sub connections to the back of the video card allowing two monitors to be connected to a single PC. Using a modern operating system such as Windows 98 the user can utilise a large desktop spanning both monitors. Although the technology is not revolutionary, it does open up the possibility of constructing a modern device more like the Memex allowing simpler hypertext authoring. Unfortunately the most innovative uses of this technology thus far have been from the games industry which has utilised these multiple screens to enhance the gaming experience.

Following this comparatively small development in hardware, the next significant change is likely to come from the use of portable laptop and palmtop computers. Instead of requiring a bulky desktop computer it will be possible to read electronic text virtually anywhere a paper-based book can be read: on the bus, in the garden, in a waiting room, etc. Besides this additional convenience, the use of such 'eBooks' could solve some of the spatial problems identified by O'Hara and Sellen (1997) in Section 4.6.4. Instead of expending effort managing a number of different windows in a fixed size CRT monitor, the user could simply load the different documents into different eBook readers and arrange them physically like sheets of paper on a desk. This scenario is often used in the cult television series *Star Trek: The Next Generation*. Thin A5-sized eBooks are used to submit reports to commanding officers. In a meeting once such officer frequently is seen to consult multiple eBooks before making a decision. But eBooks are just one of the many devices Norman (1998) terms 'information appliances'. As Norman suggests it is the synergistic use of these multiple information appliances in systems that harnesses the true power of these devices. In an educational context this could be through the use of some sort of note pad when in lectures and tutorials, an 'ePad' if you will, a number of eBooks from electronic publishers, a collection of specialist appliances provided by

the school/university, and a communications device (i.e. WAP-enabled mobile phone) to enable the downloading of the student's daily timetable. Of course for such a collection of appliances to function as a unified system, a common standard for data interchange much be established and employed.

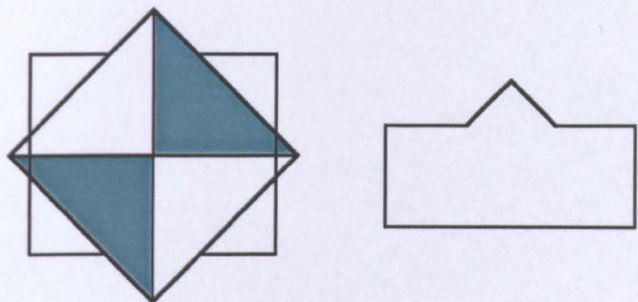
Looking slightly further into the future, it is possible that the rise of the physical information appliance will wane in the long-term. In its place the virtual reality (VR) interaction techniques explored in the science-fiction film *Johnny Mnemonic*<sup>27</sup> could become widespread. In the film the main character was able to 'physically' manipulate virtual objects in a simulated three-dimensional environment using a VR headset and force feedback data gloves. While development of such devices are described by Preece *et al.*, (1994), commercial mass-market versions are still not available. With such technology available novel educational techniques could be developed. For example, instead of reading a textbook about open-heart surgery or simply observing a consultant performing a real operation, a medical student could use data gloves to simulate the operation on a virtual patient. Such techniques would be much more cognitively efficient, both mentally and in terms of the necessary motor-skills, than reading a book or simple observation, but at the same time would not endanger any real humans.

In conclusion, although hypertext will mature in the current GUI paradigm, quantum leaps will not be possible without alternative hardware. Currently the interaction between a user and a hypertext system is mainly visual, with some auditory data for output and a mouse and keyboard for input. To become more productive, this narrow communications channel must be broadened; to do this effectively new hardware will be required.

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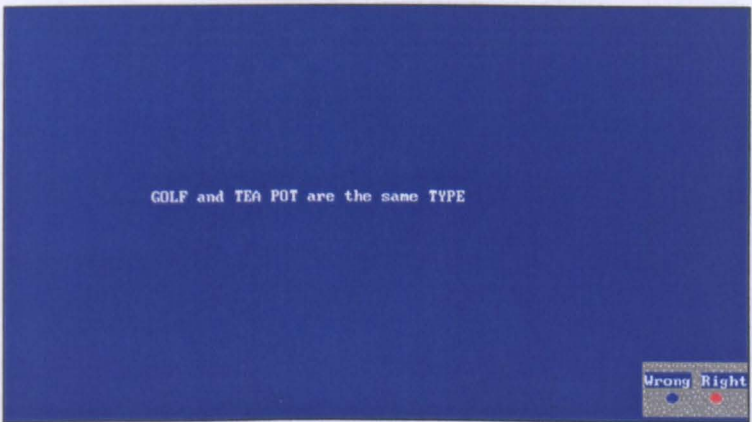
<sup>27</sup> TriStar Pictures production directed by Robert Longo. Based on a short story written by William Gibson.

**Appendix A: Cognitive Style and Spatial Ability test examples**

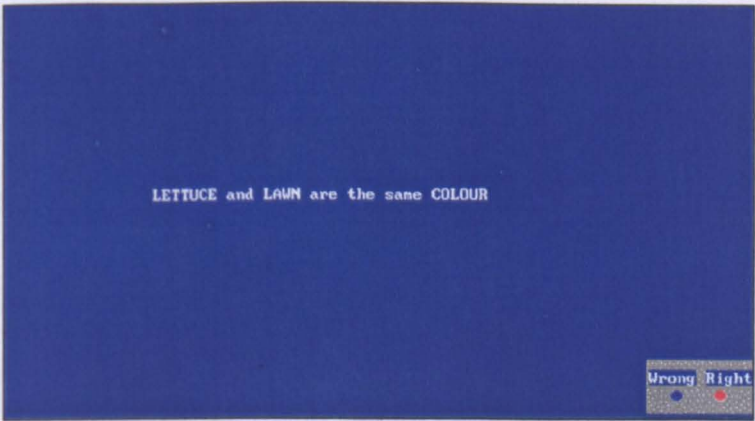


**Figure 1.** Group Embedded Figures Test example. (Find the figure on the right in the figure on the left)

*Assessing Verbaliser style:*

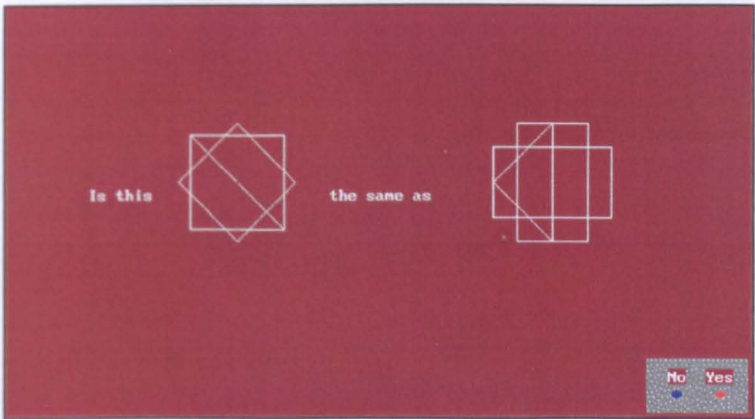


*Assessing Imager style:*





*Assessing Wholist style:*



*Assessing Analytic style:*

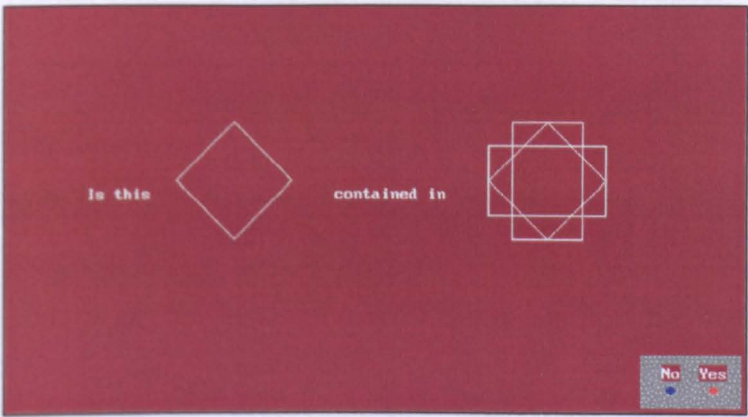
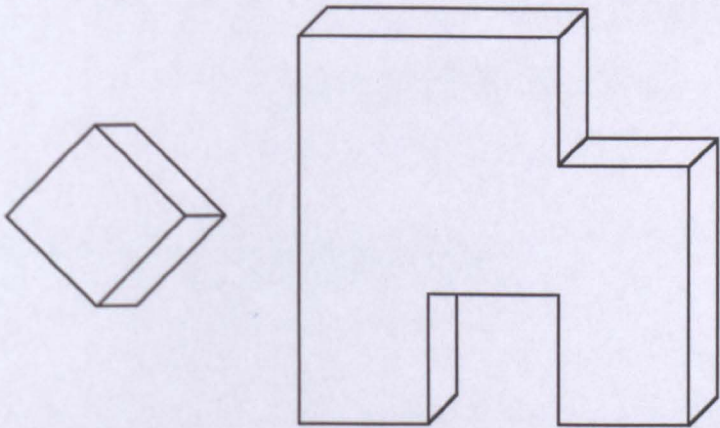


Figure 2. Cognitive Styles Analysis (CSA) test examples.



How many units like the small figure are needed to make the large figure (5, 6, 7, 8 or 9)?

Figure 3. Shapes Analysis Test example.

## Appendix B: Task 1 Questions

Name: \_\_\_\_\_

Please answer as many questions as you can in the time.

Answer the questions in the order they appear.

If you find the answer in around 30 seconds or less, tick the 'Fast' box.

If you find the answer in around 2 minutes or less, tick the 'Slow' box.

If you are stuck on a question after 2 - 3 minutes, leave it blank.

If you stumbled across the answer while looking for something else, tick the 'Returned' box.

Fast Slow Returned

1. What does CLG stand for?

☐ ☐ ☐

(Factual)

\_\_\_\_\_

2. List five disciplines which contribute to HCI.

☐ ☐ ☐

(Factual)

\_\_\_\_\_

3. Apart from Denning P.J. (1991) find another publication by Denning.

☐ ☐ ☐

(Factual)

\_\_\_\_\_

4. What is another name for a Mole?

☐ ☐ ☐

(Factual)

\_\_\_\_\_

5. Name three prototyping techniques.

☐ ☐ ☐

(Factual)

\_\_\_\_\_



Fast Slow Returned

6. How many publications in Preece et al have been authored or co-authored by Yourdon Y.?

☐ ☐ ☐

(Factual)

\_\_\_\_\_

7. State the difference between a design guideline and a rule.

☐ ☐ ☐

(Comparative)

\_\_\_\_\_

8. When using a computer what is the difference between a slip and a mistake?

☐ ☐ ☐

(Comparative)

\_\_\_\_\_

9. Define multimedia.

☐ ☐ ☐

(Interpretive)

\_\_\_\_\_

10. Who is Norman Potts?

☐ ☐ ☐

(Deductive)

\_\_\_\_\_

11. What type of software product is HyperCard?

☐ ☐ ☐

(Factual)

\_\_\_\_\_

12. Name two software development models other than the Waterfall Model.

☐ ☐ ☐

(Factual)

\_\_\_\_\_

13. Name the freelance writer who uses a computer on a bike.

☐ ☐ ☐

(Factual)

\_\_\_\_\_

Fast Slow Returned

☐ ☐ ☐

14. Apart from QWERTY, list another type of keyboard.

(Factual)

---

☐ ☐ ☐

15. In what context are verbal protocols used?

(Interpretive)

---

☐ ☐ ☐

16. Name an operating system with a graphical user interface apart from MS Windows.

(Factual)

---

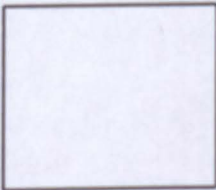
☐ ☐ ☐

17. What is the technical name for off-line communication?

(Factual)

---

18. Draw the progress indicator icon used by Macintosh systems.

☐ ☐ ☐

(Factual)

19. State one advantage of a pie menu.

☐ ☐ ☐

(Factual)

---

20. List the different types of programming knowledge experts and novices have.

☐ ☐ ☐

(Factual)

---



Fast Slow Returned

21. List four types (not examples) of icons.

☐ ☐ ☐

(Factual)

---

22. How many memory types do humans possess?

☐ ☐ ☐

(Factual)

---

23. Name another computer released by Apple Computers apart from the Macintosh.

☐ ☐ ☐

(Factual)

---

24. Name a verbal metaphor.

☐ ☐ ☐

(Factual)

---

25. List 2 evaluation techniques suitable for a small budget.

☐ ☐ ☐

(Deductive)

---

26. What is Interaction Logging.

☐ ☐ ☐

(Interpretive)

---

27. What type of mental model does a commuter have who has internalised a map of the London Underground?

☐ ☐ ☐

(Deductive)

---

28. Name a system which uses a direct manipulation interface.

☐ ☐ ☐

(Factual)

---

Fast Slow Returned

29. When in the development life cycle would you normally conduct Wizard of Oz prototyping? ☐ ☐ ☐

(Factual)

---

30. Provide an example of conflicting guidelines. ☐ ☐ ☐

(Factual)

---

31. How is a sense of presence created in virtual reality environments? ☐ ☐ ☐

(Factual)

---

32. Which is easier for panning over a large surface, trackerball or joystick? ☐ ☐ ☐

(Comparative)

---

33. Name 3 application areas of Vitrual Reality Systems. ☐ ☐ ☐

(Deductive)

---

34. Give three ways disabled users may be helped to access computer technology. ☐ ☐ ☐

(Factual)

---

35. Does Preece contain more on virtual reality than ubiquitous computing? ☐ ☐ ☐

(Deductive)

---

## Appendix C: Task 2 Questions

You have been assigned the task of developing a next generation personal digital assistant (PDA). This hand-held device will incorporate handwriting recognition and voice recognition as its primary means of input. It will also have a small LED screen and built in stereo speakers for output. Because of space limitations there will be no keyboard. Imagine you have been asked by your boss to submit a report on how the HCI team will be involved in the development of this new product to ensure a high level of usability by a wide range of different users. Your team has access to a specialised usability laboratory within the company and a generous budget.

What you are required to hand in today is a rough draft of the above report which will clearly show all the main points you will be considering in the design of the product. Please answer the question using only material from Preece *et al.*

### *Outline*

Information to include in the above report:

1. Recommend the development life cycle model that is most appropriate for the project. Explain why the development life cycle you have chosen is appropriate and why others are not for this project.
2. Name a prototyping technique suitable for developing the handwriting recognition part of the PDA. State when in the above development life cycle the technique should be used, and what its main advantages and disadvantages are.
3. Please state whether the HCI team plans to use a metaphor for the software built into the PDA. List the arguments for and against the use of metaphors and why you have decided either way.
4. Suggest a usability evaluation technique suitable for assessing the usability of the voice recognition part of the PDA. Please state when this technique should be used, what materials are needed to perform it, what type and format of information the technique provides, and how this information can be fed back into the development life cycle to improve the product.



# Appendix D: Questionnaire

## Questionnaire

Please answer all questions, except where instructed not to. Please tick applicable boxes.

1. Name: \_\_\_\_\_
2. Assigned Document Type: Book ☐ Hypertext ☐
3. Please state your total computer experience: \_\_\_\_\_ years  
(include school, university, home or work computer experience)
4. Excluding the current study, which hypertext systems have you previously used?  
(tick as many as appropriate)
 

None	<input type="checkbox"/>
World Wide Web	<input type="checkbox"/>
Microsoft Help system (includes Word, Access, etc on-line help)	<input type="checkbox"/>
HyperCard	<input type="checkbox"/>
Other (please specify) _____	
5. Which medium do you prefer to read from?
 

Paper	<input type="checkbox"/>	VDU	<input type="checkbox"/>	Either (no preference)	<input type="checkbox"/>
-------	--------------------------	-----	--------------------------	------------------------	--------------------------
6. In general did you enjoy using the document type assigned to you?
 

Very Much	<input type="checkbox"/>	Moderately	<input type="checkbox"/>	Not much	<input type="checkbox"/>
-----------	--------------------------	------------	--------------------------	----------	--------------------------

Please elaborate why: \_\_\_\_\_

\_\_\_\_\_
7. Did you experience any difficulties getting to any pages/nodes?
 

Many	<input type="checkbox"/>	A Few	<input type="checkbox"/>	None	<input type="checkbox"/>
------	--------------------------	-------	--------------------------	------	--------------------------

If 'Many' or 'A Few' then describe what these difficulties were: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

If 'Many' or 'A Few' then please state whether you ever gave up trying to get to the particular page/node you wanted:

Yes	<input type="checkbox"/>	No	<input type="checkbox"/>
-----	--------------------------	----	--------------------------

8. Excluding any difficulties mentioned in question 7, did you have any other difficulties using the document assigned to you?

Yes ☐ No ☐

If 'yes' then please state why: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

9. Did you consciously use any type of strategy when deciding which sections to read and where to go (e.g. 'I looked for overview material first and then more detailed information')?

Yes ☐ No ☐

If 'yes' then describe the strategy: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

10. What do you see as the main advantages and disadvantages of using the document type you were assigned?

Advantages: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Disadvantages: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

11. How useful did you find the following sections/facilities:  
(Book users please answer questions with a 'B' next to them, Hypertext users please answer questions with a 'H' next to them)

Contents <sub>(B, H)</sub>	Not <input type="checkbox"/>	Moderately <input type="checkbox"/>	Very <input type="checkbox"/>
Index <sub>(B, H)</sub>	Not <input type="checkbox"/>	Moderately <input type="checkbox"/>	Very <input type="checkbox"/>
Find <sub>(H)</sub>	Not <input type="checkbox"/>	Moderately <input type="checkbox"/>	Very <input type="checkbox"/>
Glossary <sub>(B)</sub>	Not <input type="checkbox"/>	Moderately <input type="checkbox"/>	Very <input type="checkbox"/>
References <sub>(B)</sub>	Not <input type="checkbox"/>	Moderately <input type="checkbox"/>	Very <input type="checkbox"/>
Figures <sub>(B, H)</sub>	Not <input type="checkbox"/>	Moderately <input type="checkbox"/>	Very <input type="checkbox"/>
Tables <sub>(B, H)</sub>	Not <input type="checkbox"/>	Moderately <input type="checkbox"/>	Very <input type="checkbox"/>
Answers <sub>(B, H)</sub>	Not <input type="checkbox"/>	Moderately <input type="checkbox"/>	Very <input type="checkbox"/>
Popup Links/Windows <sub>(H)</sub>	Not <input type="checkbox"/>	Moderately <input type="checkbox"/>	Very <input type="checkbox"/>
Back <sub>(H)</sub>	Not <input type="checkbox"/>	Moderately <input type="checkbox"/>	Very <input type="checkbox"/>
Previous Node << <sub>(H)</sub>	Not <input type="checkbox"/>	Moderately <input type="checkbox"/>	Very <input type="checkbox"/>
Next Node >> <sub>(H)</sub>	Not <input type="checkbox"/>	Moderately <input type="checkbox"/>	Very <input type="checkbox"/>

12. [For students assigned to the Hypertext system]  
When learning future topics which medium would you prefer to use?

Book ☐ Hypertext ☐ Either <sub>(no preference)</sub> ☐

Please state reason for choice: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

13. [Optional question for both groups]  
Please use the space below to raise any points not addressed above: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_



Appendix E: Experimental Data

Experiment 1

Subject		Acad.				CSA		CSA	Task 1		Task 2
ID	Sex	Age	Perform.	Medium	GEFT	W-A	V-I	Shapes	Score	Score	Score
1	1	37	67	0	15	1.12	0.85	12	14		9
2	1	23	45	1	18	1.70	0.99	15	11.5		10
3	1	26	32	0	17	0.88	1.02	18	14.5		9
4	1	22	60	1	11	1.59	1.08	11	21		10
5	1	23	50	0	16	1.41	1.01	9	13		*
6	1	48	61	1	12	2.24	0.88	11	13		13
7	1	31	50	1	12	2.49	1.45	14	6		9
8	1	21	55	1	*	1.45	0.94	23	*		*
9	1	38	59	0	9	1.39	1.06	14	10.5		10
10	1	31	48	1	6	1.41	0.99	10	5.5		*
11	1	23	70	0	16	1.38	0.88	19	16		13
12	1	29	57	0	3	0.98	1.08	10	18		4
13	1	40	68	0	14	1.39	1.04	17	18		11
14	1	34	61	0	15	*	*	20	15.5		3
15	1	23	62	1	18	2.63	1.01	18	17		4
16	1	22	52	1	17	1.12	1.10	29	9		4
17	1	57	54	0	13	1.15	1.07	14	9		*
18	1	25	61	0	14	1.03	1.06	10	15		16
19	1	29	73	0	18	1.23	1.17	17	22.5		20
20	1	24	66	0	13	2.31	1.04	19	16.5		9
21	1	31	59	0	18	1.08	1.01	16	10		10
22	1	31	56	0	8	1.13	1.06	16	13		11
23	1	22	57	0	16	1.60	1.07	11	11		9
24	1	32	62	0	13	1.49	1.03	16	20		14
25	1	22	51	0	17	2.22	1.21	24	14		16
26	1	27	62	1	11	1.30	1.14	12	12		6
27	1	26	58	0	17	1.81	1.19	17	15		17
28	1	25	70	0	16	1.25	1.07	19	13		12
29	1	28	69	0	18	1.48	1.09	17	22.5		18
30	1	30	73	1	*	1.48	1.04	19	11		11
31	1	30	63	1	12	1.71	0.80	14	13		*
32	1	24	60	1	6	1.55	0.98	6	9		13

Subject		Acad.				CSA		CSA	Task 1		Task 2
ID	Sex	Age	Perform.	Medium	GEFT	W-A	V-I	Shapes	Score	Score	Score
33	1	24	60	0	10	2.11	1.16	11	15.5		4
34	1	24	59	1	16	1.15	0.89	19	14		*
35	1	28	55	0	12	1.6	0.99	18	*		6
36	1	29	61	1	15	0.67	0.87	17	8		4
37	1	22	48	0	16	1.14	1.24	13	9.5		15
38	1	25	57	1	17	1.74	1.01	21	12		5
39	1	26	61	1	16	1.65	1.04	16	12		10
40	1	34	67	1	13	2.28	1.10	15	7.5		3
41	0	24	66	1	12	1.90	0.96	16	16.5		11
42	0	24	66	1	15	1.87	0.97	15	17		*
43	0	38	62	1	11	1.28	0.90	15	10		14
44	0	36	63	1	7	1.37	0.98	10	13		15
45	0	23	55	1	7	2.09	1.06	12	14.5		20
46	0	28	61	0	18	1.65	1.29	10	10		8
47	0	24	49	1	12	1.02	0.96	15	17.5		12
48	0	21	55	0	15	0.80	0.83	18	6.5		14
49	0	23	64	0	18	2.59	1.07	18	20		8
50	0	34	64	1	11	1.26	1.17	13	10		6
51	0	29	47	0	*	0.93	1.10	16	20		17
52	0	29	67	1	17	1.35	1.00	19	12		7
53	0	21	65	1	17	1.02	1.18	13	15		9
54	0	24	60	0	17	1.31	1.10	17	18		17
55	0	28	70	0	18	1.75	1.04	21	19		14
56	0	35	70	1	11	1.03	0.84	14	9.5		8
57	0	33	53	0	7	1.20	0.99	10	11		11
58	0	26	75	0	17	0.84	1.02	23	22		24
59	0	22	*	1	4	0.92	1.09	14	5		*

Sex: Female = 0, Male = 1

Medium: Book = 0, Hypertext = 1

Experiment 2

Subject ID	Sex	Age	Mean Acad.	Task 1	Task 2
			Perform.	Score	Score
1	0	27	67	17.5	15
2	1	27	56	17.5	10
3	0	25	80	23.5	18
4	0	29	72	24.5	13
5	0	22	57	12	5
6	1	35	72	*	11
7	1	26	66	20	12
8	1	28	60	15.5	3
9	0	23	62	18.5	21
10	0	40	57	11.5	13
11	1	27	73	19	18
12	1	24	63	13.5	9
13	0	26	69	16	14
14	0	27	66	19.5	9

Sex: Female = 0, Male = 1

Medium: All subjects assigned to Hypertext

## **Appendix F: Book documentation used in Experiment 1**

### **Human-Computer Interaction**

#### **Aims and objectives**

A concise list of the Aims and Objectives of each chapter is listed at the beginning of the chapter. This provides a useful way of determining what knowledge you should possess after reading the chapter.

#### **Further Reading**

Books and journal articles related to the current section are listed at the end of the section just after the Key Points section.

#### **Glossary (p 709)**

A Glossary is similar to a dictionary; it lists, in alphabetic order, key terms used throughout the book. Use the Glossary to read the definition of any technical words whose meaning are not understood.

#### **Header**

A Header is printed at the top of each page. The current Chapter is printed at the top of each left hand page, while the current Section is printed at the top of each right hand page. Most page numbers are also printed in the header (apart from the beginning of each chapter).

#### **Index (p 763)**

The Index, which starts on page 763 at the back of the book, lists all the main topics discussed by the book. All index entries are listed alphabetically and display the page number which covers each entry. Emboldened page numbers indicate a key discussion or definition of a topic.

If a required topic is not listed in the index under one term, try alternative synonyms. For example, if 'Windows' is not indexed then try 'GUI' or 'Operating System'.

#### **Interviews**

A unique feature of Human-Computer Interaction is a collection of short printed interviews held with important persons in the field. There are nine interviews in total which are located at the beginning and end of each main part.

#### **Key points**

A concise list of the most important concepts from each section is listed at the end of the section.

#### **Overview**

Listed at the beginning of each chapter, Overviews provide brief reviews of the main points which will be discussed throughout each chapter.

**References (p 745)**

The References section contains an alphabetical list (by surname) of all authors referred to in the book. Authors' surnames and publication dates in parentheses are used in the main body of the book so as not to interrupt the main flow of the text. Using the author and year a reader can then turn to References section at the back and discover the full bibliographical details of the article or book being referred to by the text. Parentheses containing more than one date refer to two publications generated by the same author.

**Solutions to questions (p 725)**

Throughout the book various questions are asked. The answers to these questions are listed together at the back of the book (listed in section order).

**Table of Contents**

The Table of Contents, located at the front of the book, is a list of all the parts, chapters and section in the book with corresponding page numbers. The number of pages between one section and another will give a rough impression as to how much material is contained within the section. Parts, chapters and sections are indented to show super-ordinate/sub-ordinate relationships.

**Writing Notes**

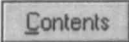
While reading any book it is often helpful to make notes as an aid to memory. The most basic method is to **highlight** certain sections of the text using highlighter pen or underlining. Further information can be concealed in **marginalia**, personal notes made in the margin or other white space area of a page. However, both of these techniques permanently alter the book. Do not use these techniques if the book does not belong to you. Instead, use a notebook to write notes. As an aid to revision it can sometimes be useful to record the chapter or page number together with notes to aid revisiting the material in the book.

Appendix G: Hypertext documentation used in Experiment

1

Hypertext Sections

1. Contents



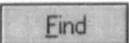
A list of the chapters, sections and sub-sections in the book. The indentation and numbering show which sections are subordinate and which are superordinate.

2. Index



The same as a book index: an alphabetical list of important persons and subjects mentioned in the book. If you cannot find a term in the index then try 'Find' (see below).

3. Find



An alphabetical list of every single word in the book. If the word does not appear in 'Find' then it is not used in the book.

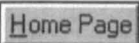
4. References

A list of references to publications mentioned in the book, sorted by authors' surname. Unlike a book there is no complete list of references in one place. Popup references are signified by green dotted-underlined text. Also, the more important references are listed in the index, and all authors are indexed in the 'Find' section.

5. Glossary

An alphabetic list of terms specific to HCI with their definitions. Words in green and have a dotted-underline, but which are not references, are popup glossary terms. Alternatively click on the 'Contents' button (see above) and then scroll down to the bottom where every glossary term is listed.

6. Home Page



Click on this button to return directly back to the start of the hypertext. This button can be useful if you become lost at any point.

## Navigation

### 1. Jump Links

Any word in green which has a solid underline signifies a jump link activation point. Click anywhere over this word to select the link. If the new node is not satisfactory then click on the 'Back' button (see below).

### 2. Popup Links

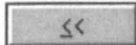
Any word in green which has a dotted underline signifies a popup link activation point. Click anywhere over this word to select the link. Once selected a small popup box will display either a glossary term or a reference. To dismiss a popup box click anywhere on screen.

### 3. Backtracking



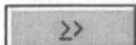
Click on this button to return to the previous node. It is similar to a multilevel undo button. Do not confuse this facility with the 'Previous' button (see below).

### 4. Previous Section



Click on this button to go to the previous section. For example, if in the book you were in section 4.3, clicking on this button would go to section 4.2. The only sections not accessible from this linear sequence are: figures, tables, boxes, references, and the glossary.

### 5. Next Section



Click on this button to go to the next section in the document. For example, if in the book you were in section 4.3, clicking this button would go to section 4.4. The only sections not accessible from this linear sequence are: figures, tables, boxes, references, and glossary terms.

## Manipulating Information

### 1. Bookmarks

If you need to return easily to the current node at a later date a bookmark can be left to solve the problem. Select 'Define' from the 'Bookmark' pull-down menu, enter a suitable name that you will remember and click on 'OK'. Bookmarks can also be deleted by selecting 'Define' again, click on the name of the bookmark to be deleted and then click 'Delete'.

### 2. Annotation

User annotations can be made by selecting 'Annotate' from the 'Edit' pull-down menu. Enter the required annotation in the text entry area and then click on 'Save'.

(see example below). A green paper-clip in the top left corner will signify any annotations made on the current node. To delete an annotation that is no longer required select 'Annotate' from the 'Edit' menu and then click on the 'Delete' button.

### 3. Longer Notes

To make longer notes select 'Run WordPad' from the 'Edit' pull-down menu. This will launch the Windows 95 word processor - WordPad. To copy text between the hypertext and WordPad, first highlight the required text in the hypertext, select 'Copy' from the 'Edit' pull-down menu, switch to WordPad and select 'Paste' from the 'Edit' pull-down menu.



## Appendix H: Hypertext documentation used in Experiment

2

Advantages:

### Windows 95 - Important Features

#### 1. Minimize Icon



This will minimize the current window. To restore a window once minimized see the Task bar.

#### 2. Maximize/Restore Icon



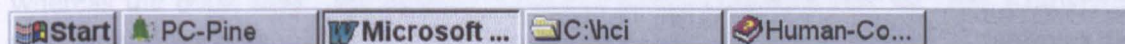
When the above icon is displayed the application can be maximized. If however the application is already taking up the whole screen then the following icon will restore the window to its original dimensions:

#### 3. Close Icon



This icon when clicked will close the current window. If the main hypertext window is closed then the whole application will terminate including all secondary and popup windows.

#### 4. Task Bar



The Task Bar contains the 'Start' button and is used for starting applications. It also contains a list of all currently running applications and windows. Each button represents one window. The example above shows 3 applications running (PC-Pine, MS Word, and Human-Computer Interaction). The 'C:\hci' button is a desktop window showing the contents of that path. The application which currently has focus is MS Word which appears depressed. To switch between applications select the appropriate button (or application title) from the task bar.

If for any reason the Task Bar is not visible at the bottom of the screen then it is probably because 'Auto Hide' is on. Just move the mouse to the bottom of the screen and the Task Bar will reappear.

## Hypertext as a Technology

---

### Advantages:

There are many new knowledge domains which are inherently complex and nonlinear. Human-Computer Interaction (HCI) is one such domain which is informed by many separate fields, including among others: computer science, psychology, ergonomics, sociology, anthropology and design. Although there are good books available on HCI, and other complex subject areas, it is becoming increasingly difficult for any one book to accurately capture the complexity and subtlety of the many facets of each domain. Hypertext is a new medium which might provide several advantages over books. For example, one of its main strengths is its ability to externalise structure by providing visible links between nodes which a user can select. The idea behind this linking is generally traced back to a paper written by Vannevar Bush in 1945 describing a fictitious machine called Memex. Although the machine never built, Bush was interested in trying to automate the processes with which the human brain works. He suggested that with one item in its grasp the mind snaps instantly to the next which is associated with that thought. Using links enables sophisticated networks to be established through a body of literature. This avoids what Bush referred to as the artificiality of traditional indexing systems. Instead of compartmentalising knowledge, links can be inserted anywhere required. Although the idea behind hypertext was created more than fifty years ago, it was not until the personal computer arrived did hypertext start to be widely used. Part of this was due to the HyperCard hypertext system being bundled with new Macintosh computers. Today the Internet is probably the most widely used hypertext system in existence, followed closely by online help systems.

Human-Computer Interaction by Preece *et al.* is implemented using the Microsoft Help engine which ships with Windows 95 and Windows NT 4.0. This digital implementation replicates the contents of the book as closely as possible. The hypertext version does, however, take advantage of hypertext's link facilities. For example, whereas the book says 'See chapter 6', the hypertext replaces this by 'See Knowledge and Mental Models'. This has two advantages over the book: firstly it **removes the burden** from the user of having to remember what chapter 6 is about without consulting the table of contents, and secondly the reference may be clicked to go straight there. This second advantage **saves time** because the user does not have to find out which page chapter 6 starts at.

References and Glossary Terms are implemented as popup nodes which are displayed in small windows on top of the main hypertext window. This not only saves looking down long sections of references, but also **preserves the surrounding context** of the information (the chapter containing the reference is still visible behind the popup window).

In addition to a similar table of contents and index the hypertext also has a **full text search engine**. This engine keeps track of where every single word in the document is

used. All that is required is to enter a word or phrase and the system will return the names of all nodes which contain the required words.

### **Disadvantages:**

Books because of their physical **size and properties** give the user clues as to how much information is contained. The size of a hypertext system in megabytes gives little indication. A 2Mb document which is composed entirely of text is large, but a 2Mb hypertext containing high definition colour photos could be quite small. Also, because books are read from front cover to back, readers can observe their progress through the book by the thickness of the pages on the left compared with the right.

One problem which is mentioned throughout the hypertext literature is that of '**lost in hyperspace**'. This is when the user does not know either how they got to the current node, or how to get to a node which is known or thought to exist. Disorientation occurs when insufficient navigational cues are provided. The current implementation of HCI provides a clickable set of links at the top of all the main nodes. This set of links represents the current branch from the table of contents. It shows all parent nodes of the currently displayed node and children nodes one level down. Also, the current node's name is displayed at the top of the display in the non-scrollable region.

The **full text search** engine is undoubtedly a useful addition to the electronic version of the book, however it does have some disadvantages if misused. The first problem is that the search engine applies no intelligence to the search so it sees glass windows and Microsoft's Windows as the same type of window. Secondly, some words such as 'the' may be used in just about every node in the hypertext. Thus, the most sensible use of the hypertext would be to use the author built index first which contains only the main topics dealt with in the book, and then if unsuccessful to try the find facility.






## Important Sections

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### 1. Table of Contents

Contents

The table of contents is exactly the same as the book version of Human-Computer Interaction. The whole contents is displayed as a hierarchy of topics. Topics listed with a book icon  next to them contain sub-topics, double click with the mouse to expand. Double-clicking on an expanded topic  will close all subordinate topics on that branch. Topics listed with a page icon  with a question mark will display the actual topics when clicked on, these do not expand any further.

### 2. Index

Index

The table of contents presents the names of topics only not the actual subject covered within each topic, so there may be times when you do not know which topic the information you require is in. In these circumstances use the index which provides a finer granularity of information. The index is listed alphabetically, just double click any required terms and the hypertext will jump directly to the relevant topic.

### 3. Find

Find

If you cannot find the required term in the index but you think the information is in Human-Computer Interaction there is a third information searching tool built into the software - Find. This tool automatically indexes every single word in the complete document. Type in the word(s) required and a list of topics which contain this word(s) will be listed. Double click on any of these topic names to jump directly to the topic.

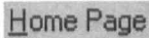
### 4. References

Unlike the book there is no section listing all the references in one place. Where each reference occurs in the text there is a pop-up link. Alternatively if you do not know where to find the link, use the find facility (see above) and type in the author's name.

### 5. Glossary

The glossary can be found at the bottom of the table of contents (see above). The glossary is used to provide definitions for commonly used terms in the hypertext. Pop-up links which are not references will display glossary definitions as well.

## 7. Home Page



Click on this button to return directly back to the start of the hypertext. This button can be useful if you become lost at any point.

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## Navigation

### 1. Jump Links

Any word which is underlined in solid green signifies a jump link activation point. To select the link just position the mouse over the word and single click. If the new node is not satisfactory then click on the 'Back' button (see below).

### 2. Popup Links

Any word which is underlined in dotted green signifies a popup link. This type of link will display the destination node in a small popup window (see example below). Once displayed to remove the window just click once on the mouse (either over or beside the window).

**Winograd T. and Flores F. (1986)**

*Understanding Computers and Cognition: A New Foundation for Design.* Norwood, NJ: Ablex

Popup links are used for all References and all Glossary Terms.

### 3. Backtracking



Click on this button to return to the last node displayed. It is similar to a multilevel undo button. Do not confuse this facility with the 'Previous' button (see below).

See History List for related information.

### 4. Previous Section

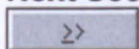


Click on this button to go to the previous section. For example, if in the book you were in section 4.3, clicking on this button would go to section 4.2. Select again and section 4.1 would be displayed. The only sections of the book excluded from this linear sequence are: figures, tables, boxes, references, and glossary terms.



See 'Next Section' for opposite functionality.

## 5. Next Section

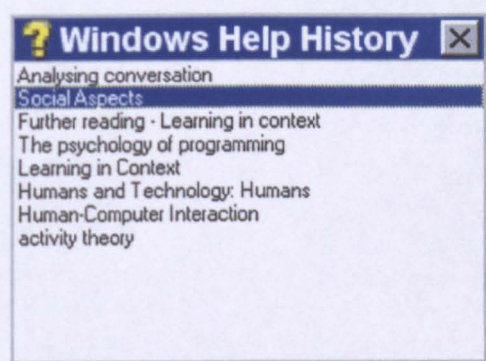


Click on this button to go to the next section in the document. For example, if in the book you were in section 4.3, clicking this button would go to section 4.4. The only sections of the book excluded from this linear sequence are: figures, tables, boxes, references, and glossary terms.

See 'Previous Section' for opposite functionality.

## 6. History List

The history list as shown below represents a chronological list of all nodes visited in the current session (most recent at the top). To display this window select 'Options' and then 'Display History Window...'. To go directly back to any previously visited node just locate its name on the list and double click with the mouse.



The history list window is resizable and can be closed by clicking on the close icon (the cross in the top right corner). The history window, when open, stays on top of the main hypertext window at all times.

## Manipulating Information

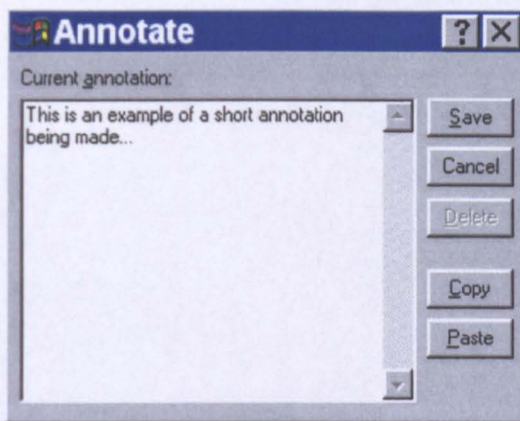
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### 1. Bookmarks

If you need to return easily to the current node at a later date a bookmark can be left to solve the problem. Select 'Define' from the 'Bookmark' menu, enter a suitable name that you will remember and click on 'OK'. Bookmarks can also be deleted by selecting 'Define' again, click on the name of the bookmark to be deleted and then click 'Delete'.

### 3. Annotation

User annotations can be made by selecting 'Annotate' from the 'Edit' menu. Enter the required annotation in the text entry area and then click on 'Save' (see example below). A green paper-clip in the top left corner will signify any annotations made on the current node. To delete an annotation that is no longer required select 'Annotate' from the 'Edit' menu and then click on the 'Delete' button.



### 3. Longer Notes

To make longer notes select 'Run WordPad' from the 'Edit' menu. This will launch the Windows 95 word processor - WordPad. To copy text between the hypertext and WordPad, first highlight the required text in the hypertext, select 'Copy' from the 'Edit' menu, switch to WordPad and select 'Paste' from the 'Edit' menu.



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