NAVIGATIONAL ISSUES IN HYPERTEXT-BASED LEARNING

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DECLARATION

Work for this thesis has resulted in the following publications:–

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2 Hammond, N V & Allinson, L J (1988), *Travel around a learning support environment: rambling, orienteering or touring?*, in Proceedings of CHI88: Human Factors in Computing Systems (Soloway, E, Frye, D & Sheppard, S B, eds), ACM Press, New York, 269-273

3 Hammond, N V & Allinson, L J (1988), *Development and evaluation of a CAL system for non-formal domains: the Hitch-hiker's Guide to cognition*, Computers and Education **12**, 215-220

4 Allinson, L J & Hammond, N V (1989), *A learning support environment: the Hitch-hiker's Guide*, in Hypertext: theory into practice (McAleese, R, ed), Intellect Books, Oxford, 62-74

5 Hammond, N V & Allinson, L J (1989), *Extending hypertext for learning: an investigation of access and guidance tools*, in People and Computers V (Sutcliffe, A & Macaulay, L, eds), Cambridge University Press, Cambridge, 293-304

6 Allinson, L J & Hammond, N V(1990), *Learning support environments: rationale and evaluation*, Computers and Education **15**, 137-143

7 Allinson, L J (1990), *Designing and evaluating the navigational toolkit*, in Proceedings of the NATO Advanced Educational Workshop "Cognitive Modelling & Interactive Environments", Mierlo, The Netherlands

ABSTRACT

Computer-assisted learning (CAL) systems are not only a product of the available technology but also of the changing conceptions of the roles of education and educational practice. A discussion is presented on the development of learning theories and the provision of CAL systems. In particular, the advantages and potential problems of hypertext presentation systems. The cognitive principles on which my approach to CAL have been founded are introduced, and the manner in which these principles are realised in an exampler system - the **Hitch-hiker's Guide**. This system is referred to as a learning support environment as it is intended to supplement conventional teaching methods rather than to replace them, and to be a flexible system where the locus of control can be shifted effortlessly between the user and the computer. Considerable emphasis has been placed on making the interface as transparent as possible and on the provision of a range of navigational tools to aid a variety of learning needs and styles. Extensive evaluation of the system has demonstrated that users do use all of the system facilities and in a manner appropriate to the current task. An investigation of user behaviour and its relationship to their individual learning style (based on responses to an Approaches to Study Inventory) indicates that navigational techniques are, in part, a function of learning style. The implications of these experimental findings for the design of CAL systems are discussed.

For Les and Joan

CHAPTER 1

INTRODUCTION

1.1 Overview

The research project, which forms the basis of this thesis, was application-driven in that a prime goal was the production of a useful and usable piece of software for the delivery of computer-based teaching in cognitive psychology within the Department of Psychology at York. As a psychologist first and foremost, the given programming task could not be undertaken without regard to two clearly vital and largely psychological issues – educational objectives and human-computer interface design. The software needed to satisfy the educational objectives of our students and could do so only if the computer itself presented no barrier to the learning process. Hence, establishing clear educational objectives, and the form of interface in which they were to be implemented were the starting point and not the then available or emerging technology. The use of student testing at all stages of the design and implementation of the system along with the subsequent data collection owes much to the methodology of the discipline of psychology. At one level, user feedback improved interface design; at a higher level it helped us revise and reformulate our understanding of the learning process and our approaches to supporting teaching with computers.

I will concentrate on the design, development and evaluation of a specific software solution to computer-assisted learning (CAL). Discussion of any particular solution cannot however occur in isolation and so the first part of this Chapter briefly outlines the educational, psychological and technological background that impinged on my work, and the environment in which the resulting solution occurred. The second part of this

Chapter introduces hypertext (i.e., a non-linear access method to information), which forms the basis of our approach to CAL and discusses its general application. The use of hypertext specifically for learning is considered, together with its advantages and disadvantages. The major disadvantages (and possibly its advantages) centre on user navigation around the information space. The major emphasis of this work is to provide solutions to these problems of navigation and to do so in a way that will support our educational goals and objectives. The final part of the Chapter will provide an overview to the work presented in this thesis.

1.2 Theories of Learning

During the last two decades paradigm shifts have been taking place for both cognitive psychology and educational practice. The view of learning as the relatively automatic product of environment and circumstance that gives rise to a new or learned responses (as exemplified in the passive model of learning based on the concepts of classical or instrumental conditioning) has given way to the model of the learner as an active, self-determining individual possessing complex information processing mechanisms. This generates the view of the learner as an interpreter, processor and synthesizer of a continual barrage of information, both from their external environment and from their own internal thinking processes. West & Pines (1985) highlight the trends in education and psychology that have given rise to the new approach as:–

- The shift to cognitive psychology with its interest in the "learner-in-the-process-of-learning".

- The methodological shift towards qualitative studies.

Understanding the learning process requires an understanding of a number of distinct internal states of the learner such as information storage and retrieval capabilities, intellectuals skills and cognitive strategies (Gagne & Briggs, 1974). At the outset of learning, a learner must already possess a certain information base necessary to understand the new content, have intellectual skills such as problem solving, concept acquisition and discriminatory learning skills, and the necessary cognitive learning strategies to govern behaviour and manage learning (namely, information storage/retrieval and problem solution).

Most work on learning, where learning is seen as eliciting cognitive structure and bringing about conceptual change, has been carried out in the area of science teaching. The research generally has been to focus on the learning of coherent bodies of information not on the learning of discrete concepts and skills (since science usually consists of well-developed and highly structured bodies of knowledge). West & Pines (op. cit.) would claim that the findings from this research are not confined, however, to the learning of science.

A number of theories of learning within this paradigm have been proposed. Ausubel (1963) claims that learning results when a person explicitly ties new knowledge to relevant concepts or propositions they already possess. His assimilation theory of learning is illustrated in Figure 1.1.

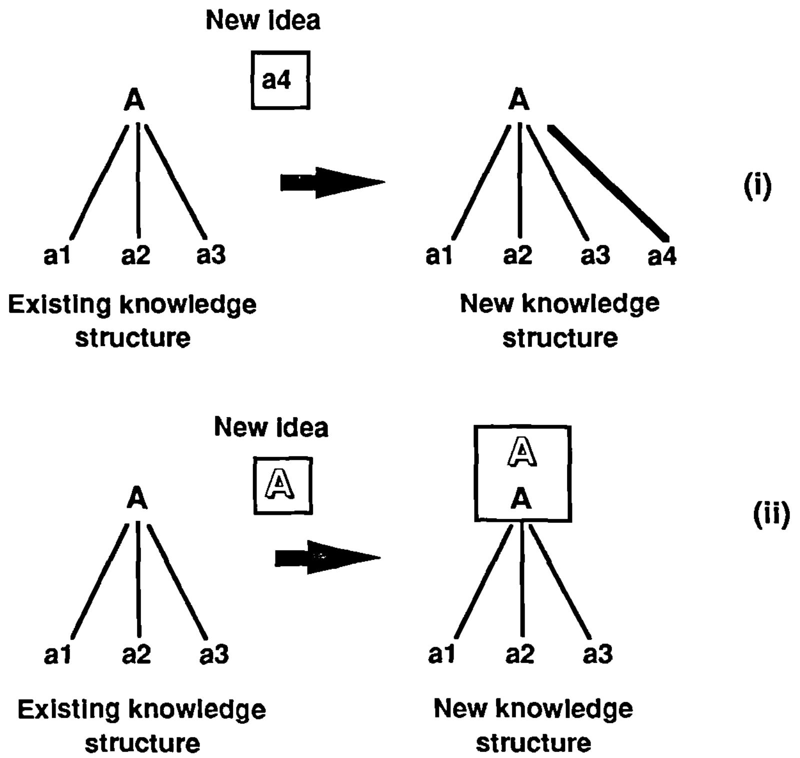


Figure 1.1 Illustration of Ausubel's assimilation theory of learning (i) subordinate learning; (ii) superordinate learning

- **Subordinate learning**

New information is linked to a superordinate idea A and represents another case or extension of A. The critical attributes of A are unchanged – but new examples are recognised as relevant.

- **Superordinate learning**

The established ideas **a1, a2,** and **a3** are recognised as more specific examples of the new idea **A**, and hence become linked to **A**. The superordinate idea **A** is defined by a new set of criteria attributes that encompass the now subordinate idea **A**.

Ausubel has greatly extended these ideas of this structuring of the individual's knowledge base. Meaningful learning, therefore, requires that the individual is able to internalise new information or *stimuli*, and perhaps more importantly, enables the learner to utilise this new knowledge to other situations. This contrasts with rote learning where new knowledge is arbitrarily incorporated into the cognitive structure, to where the individual is able to recall the new information but is unable to apply it in solving new problems.

Thomas & Harri-Augstein (1985) define learning as "the construction, reconstruction, negotiation and exchange of personally significant, relevant and viable meaning." This is a dynamic vision of learning concerned with elaborating structures of meaning by the self-organisation of one's own behaviour and experience to produce changes that are of personal value. Their central model is that of an accompanying internal conversation as learners reflect on, and critically manipulate, the learning material. They clearly acknowledge the onus on learning to be with the learner and state that "learning how to learn is not the same as successfully submitting to be taught." They see this self-organised form of learning as purposive, alive, relevant and viable; whereas learning organised by others inevitably leads to boredom and dissociation with the topic. The mechanistic approach of the behaviourists to learning is expressed by Bannister (1985) as "the human subject remained a pale and shadowy figure, lost between the stimulus (as defined by the psychologist) and the response (as defined by the psychologist); an *organism* without self possessed point or purpose."

This active and constructionist approach to learning is echoed by other workers. For example, Ausubel (1985) has aptly summarised the objectives of education as "the long-term acquisition of valid and usable bodies of knowledge and intellectual skills and the development of an ability to think critically, systematically and independently."

West & Pines (1985), share this constructionist view of learning, and identify two sorts of knowledge in the individual (following Vygotsky, 1962):–

- That which is acquired through interaction with the environment – "a person making their own sense of the environment which she observes, tempered and manipulated by her interaction with parents, peers, television and other influences."

- That which is acquired through formal instruction which they see as "someone else's interpretation of the world."

Learning is viewed therefore as an integration of these two sources of knowledge. They use a vine metaphor to illustrate how the two sources of knowledge becomes intertwined to produce genuine conceptual learning. They find it useful to distinguish three processes – conceptual development, conceptual resolution and conceptual change. Conceptual development involves integration and differentiation of concepts, which constitutes a first step towards understanding. Conceptual resolution involves the resolution of conflicts between existing and new knowledge; and conceptual change means abandoning one set of conceptual understanding for another irreconcilable set.

The prime aim of education, especially at the higher levels, is to attain a state of meaningful learning in students. From the viewpoint of Ausubelian psychology and drawing on the results of several studies conducted by Bransford & Johnson (1972), a key factor in the potential for success in meaningful learning is the building of a framework of relevant concepts and propositions. Cognitive conceptions of learning and acquisition of new concepts have placed considerable importance on prior knowledge. As Bransford & Franks (1976) express it:–

> "... growth and learning do not simply involve an expansion of some body of interconnected facts, concepts, etc. Learning involves a change in the form of one's knowledge so that it can set the stage for new discoveries."

A student's struggle with unconnected ideas in a complex knowledge area will necessarily lead to rote learning. If students are presented with concepts in isolation, and are expected to learn them in a given sequence not compatible with their own current understanding, the student is faced with the burden of rote memorisation. This frustrating emphasis on reproducing information as presented can lead to inflexible and uncritical thinking (Ault, 1985). Many workers, for example, advocate the use of mapping exercises (Okebukola, 1990; Novak & Gowan, 1984; Fischer, 1986) to help students formulate and elaborate their cognitive structures.

The view, therefore, that learning occurs only with the full participation of the learner who actively organises and purposively pursues a given interaction towards a learning goal, leads us away from an instruction-based approach to teaching and information provision and towards a learner-centred, learner-controlled, learning environment. Naturally, this view of learning and the role of learners and instructors in the learning process will result in the provision of computer-based learning materials, widely differing from those produced within the mechanistic Behaviourist paradigm based largely on the work of Skinner who so greatly influenced previous educational practice. CAL must, therefore, incorporate mechanisms that permit the user to structure and re-structure their own knowledge base in response to the information, ideas, or concepts presented. The previous paragraphs are not intended to be a comprehensive review of learning theories, but an overview of the paradigm shift that has occured in recent years. The designer of computer-based systems needs to be mindful of the processes involved in learning and of the available current theories of learning as distinct from theories of instruction that have dominated much of educational practice. Successful CAL systems will need to support a variety of perspectives on any given knowledge domain.

Many of the ideas generated by these new theories of learning, though impelling and influential in altering educational practice, have still to be empirically tested and verified. Just how user-centred should learning be? What level of influence should the instructor provide? Is the provision of full learner-control always appropriate? The answers to many of these questions may be dependent on our educational objectives, the precise information we are trying to convey, both in its complexity and its relation to previous knowledge that may exist in the learner, and also the learner's own abilities and motivations.

1.3 Complexity of Knowledge

Coupled with our regard for the theories of learning, we cannot have full understanding of the learning process without regard to the materials to be learnt. Only if we believe that knowledge is composed essentially of isolated facts to be committed to memory can support be given to the use of passive rote-learning methods. Work in the field of cognitive science has shown that knowledge is composed of complicated interacting networks of information and skills. The structure of knowledge is complex – not only are there isolated facts but there are hierarchies, relational networks and combinational sets. Furthermore, knowledge can be viewed from a number of perspectives. For example Shuell (1987) discusses aspects of the nature of knowledge, including its locus and type. *Locus* refers to whether knowledge exists in an independent objective form or whether it exists primarily in the mental representations of like-minded individuals. For many disciplines, there is controversy, conflicting explanations of the same experimental evidence (even conflicting evidence), historical perspectives, subjective opinions – as well as hard isolated facts. Even in the physical sciences, as Gilbert, Watts and Osborne (1985) have noted, there are different locations and hence representations of scientific knowledge – ranging from the *scientist's science* to *children's science.* An explanation of a physical phenomenon in terms of Newtonian mechanics may be sufficient for one locus of knowledge, but for another only General Relativity Theory or even String Theory is adequate. And yet, without regard to the learner or the learning materials, many educational practices and technologies place learners in an essentially passive role in which they are expected to simply learn because they are told to do so – that is, to absorb information or skills automatically as a result of being exposed to the *right* teaching methods or curriculum.

West, Fensham and Garrard (1985) also distinguish between public knowledge and private understanding. Science exists as public knowledge (in text books and scientific papers). An individual on reading these will interpret and analyse this public knowledge to produce a personal understanding, which will change again on repeated or further reading. They claim that the different understandings result from different information being missed on each occasion and information being put together in different ways. In their model, new information is related to existing knowledge and experience and are hence necessarily idiosyncratic. Private understandings are not fixed nor are they commonly shared, and certainly they are not the same as the public knowledge. Again, this suggests a flexible approach is needed for successful CAL systems and that the user of such systems needs to be able to manage their own learning.

1.4 Learner control

Student control is of crucial importance in effective learning. Whether or not students themselves should be given control over the sequencing and nature of learning activities – in short over their own learning – has been the topic of much research and debate. As Merrill (1983) points out, there are two basic types of learner control:–

- Control of content (the learning material)
- Control of strategy (e.g., facilities for access, depth of presentation, note-taking, practice questions).

As Laurillard (1987) comments "...there is no well established reason to suppose that a program designer, whether teacher, researcher or programmer, knows better than the student how they should learn. Therefore when we are designing materials for a medium that is capable of providing an unusual degree of individualisation via student control, it seems perverse not to take advantage of it." Research on the usefulness of extending the learner choice of actions has provided conflicting evidence, though it should be noted that many studies have been based on a limited range of learner control options in a specific, usually formal, knowledge domain. Fry (1972) suggested that freedom led to inefficient learning, but Hartley (1981) demonstrated that learner control could be more effective than program control. Rubicam & Oliver (1985) considered a number of studies – again with confusing conclusions. Their findings did suggest that students who adopted a consistent strategy performed significantly better than those who were inconsistent. An investigation of a CAL system that permitted either the linear or selected branching of information screens (Gray, 1987) suggests that students who experienced the branching option performed better in comprehension-based tests but no difference in retention-based tests. While one can extract some reasonable *rules of thumb*, such as that usually knowledgeable learners are in a better position to capitalise on freedom of choice than relative novices (Garheart & Hannafin, 1986; Gay, 1986), the important point is that, as with many issues in educational technology, the optimal locus and nature of control is strongly dependent on contextual factors. A rigid allocation of control (either by the system or the learner) is unlikely to be suitable across a range of domains, learner types and learning tasks.

Many authors have argued that not only should a CAL system support appropriate learning strategies but that it should also be compatible with the student's own approach to learning. This argument claims that CAL systems, by providing a restricted form of presentation, confine the student to a particular learning strategy and are likely to fail a substantial proportion of learners. Linear presentation will frustrate the student who, whether through inclination or current state of knowledge, wishes to learn by first gaining an overview, whereas a totally user-centred environment may overwhelm a student with the need for a more serial approach to learning. Although there is some evidence that students can be taught appropriate strategies to enhance learning, for example through the use of concept mapping techniques (Novak & Gowin, 1984; Novak, Gowin and Johansen, 1983), the relationship between strategy and learning outcome is not always obvious. Learning strategies, as with instructional methods (Fraser & Edwards, 1985), may have differential effects on performance depending on student skills and aptitudes. Stensvold & Wilson (1990) found that low ability students (as measured with an ITED vocabulary subtest) who used previously-taught concept mapping techniques did better than a control group of students who had not been taught these techniques, whereas high ability students did worse than the controls. The terms *style* and *strategy* have been used in a rather loose manner in this Section, and Chapter 5 will discuss in detail the relevance of cognitive styles and strategies to learning. Irrespective of a user's preferred style, the building of a knowledge base by assimilation of new material should always be encouraged and the flexibility for users to approach the material from a number of perspectives, and a distinct and visually-rich environment will greatly aid meaningful learning.

1.5 Parallel developments in CAL

1.5.1 Early history

The history of the development of computer-based teaching (CBT), to use the original term, in some extent has followed the course of educational philosophy and practice but has probably been more greatly influenced by the available technology and skills of the developers. The teacher, often working in isolation, as few colleagues were prepared to devote much time and energy in acquiring the necessary programming skills and with minimal computing facilities often represented a 'hobbyist' approach to CBT development. Assimilation and distribution of such materials was difficult. The researcher, often working at the forefront of technology, was more freely able to investigate innovative program design but often lacked the domain knowledge, or the understanding of the educational goals, of the teacher. For the most part, the bulk of early teaching software was of a tutorial nature that utilised simple text presentation. The traditional drill and practice approach (reminiscent of the Skinnerian programmed learning paradigm) prevailed, but now with linear or even optional branching mechanisms as a concession to student control. The shortcomings of such programs are that they are prescriptive and inflexible and favour the acquisition of only limited forms of knowledge. It is instructive to note the change in the descriptive title of such work – from CBT to CAL; that is from *teaching* to *learning*.

1.5.2 Intelligent tutoring systems

By the early 1980s there was a widespread dissatisfaction with educational software provision. This dissatisfaction was summarised by Hawkridge (1983) as "...critics of the new information technology point out, with some justice that the courseware available so far for use with the new machines is inadequate in quality, quantity and variety." Within computer and cognitive science research disciplines, artificial intelligence systems were being hailed as the answer to many problems. Their application to improve CAL systems was being strongly argued by O'Shea & Self (1983) amongst others (see Sleeman & Brown, 1982). Self (1984, 1987) gives a definition of artificial intelligence (AI) as "the science of getting computers to do things which would be considered intelligent if done by humans." AI research aims to build more useful computer systems (often by natural language interfaces that mimic human conversation) and to understand the nature of intelligence and associated cognitive abilities. This full understanding is required as intelligent tutoring systems depend on the existence of a (machine) working memory which represents the current state of the *world* (i.e., the knowledge domain, the instructional strategy of the learner and a set of production rules). Self, writing in 1974, was optimistic that programs with natural language dialogues that were perhaps indistinguishable from traditional teacher – student dialogues could and would be achieved within a five-year timespan. Writing in 1984 and 1987, he admits that he was wrong and states "we are little nearer today to knowing how to write such a program than we were in 1972." Self admits that this new era in computer aided instruction has been slow to come and emphasises the fundamental difficulties that he sees can only be overcome by progress within the field of psychology.

> "Technically, the components of such systems seem to be inextricably intertwined: it seems impossible to focus, for example, on the learner model without considering the details of its ramifications on the interface, the domain knowledge representation, the didactic component, and so on" (Self, 1990).

Self goes on to state that these decisions have to be justified against broad educational, psychological and philosophical considerations. As yet, little has been achieved in the formulation of formal principles and conceptual frameworks to aid development of such programs. Because of this complexity, AI systems have been successful only in limited knowledge domains, which are formal in their organisation and dependence on logical analysis – such as mathematics and some branches of the physical sciences. Despite these successes, non-formal knowledge domains, as yet, cannot be described in terms of a logical calculus – let alone can the learner be described in such terms. Hence, intelligent tutoring systems, in their current state of implementation, are not seen as an answer to all our tutoring requirements. A more negative view of available intelligent tutoring systems is that they can force users along a route nearly as restrictive as the straightjacket of programmed rote learning. It is the designers of the system, not the system or the student, who learns by experience as the system is used. It is they who modify the production rule database accordingly. The educational philosophy of using such intelligent approaches is often questionned. It is useful to repeat some quotes from Megarry (1988) highlighted in a paper by Hammond (1989):–

> "A false trail has been laid by intelligent tutoring systems that try to create a model of the student ... To treat the learner as a dumb patient and the computer system as an omniscient doctor is both perverse and arrogant".

It is therefore wise to caution the limited range of applicability of intelligent tutoring systems and their restrictive role for the learner. Intelligent tutoring systems also have problems at the practical level, as Self (1987) concludes "...the practical application of artificial intelligence research to computer-assisted learning would demand skill and resource way beyond those used at present to develop educational software. As a result, therefore, most designers will probably continue to regard this research as irrelevant to their needs."

1.5.3 Authoring systems

Neither the hand-crafted approach to computer-based teaching nor the intelligent tutoring approach provided a solution to getting good software, in quantity, to a large user base. Both approaches were costly in terms of development time and skill requirements. The former approach was dominated by enthusiastic educationalists often with little appreciation of program or interface design, but an obvious grasp of both the domain knowledge and teaching objectives. The latter approach was adopted by the computer scientist or *knowledge engineer*, who was unlikely to have the necessary domain knowledge and teaching skills. Consequently computer-based teaching methods were often criticised as not being cost and/or educationally effective, and by and large too difficult for use.

The development of authoring languages and more lately authoring systems were an attempt to overcome some of the problems as they were designed to be used by the subject experts rather than the professional programmer. Authoring languages such as **Pilot™**, **Microtext,™ Plato™** and **Tutor™** were purpose-designed delivery systems that could easily handle different styles of questions (though often only with very rudimentary text parsing of the student's answers), and allowed virtually unrestricted forward and backward branching (usually based on student's scores) in any number of parallel strands. They could keep running totals of scores in a number of categories and allocate different marks to different questions. A full review of authoring languages is given by Barker (1987). Although these fourth-generation languages made it relatively simple to create computer lessons in very little time, the structure of the resultant lessons were highly restrained, and applications other that tutorial programs were difficult. These limitations are amplified by Denenberg (1978, quoted in O'Shea & Self, 1983) who, in discussing Tutor and Plato languages, suggests that whereas simple programs were easy to write, more complex programming using the available structures required a high degree of expertise – beyond that of many professional programmers.

Whatever the shortcomings of the authoring approach to CAL materials, these languages did bring the possibility of program creation to a far wider audience, and in so doing, the field of computer-based teaching was expanded. The issues involved in CAL, namely discussion of its aims and desired objectives and to some extent its evaluation were made possible by its increased realisation through authoring systems. Some problems encountered during the first phase of authoring language development have been addressed by developments in more recent hardware and software provision, but the basic notion of the general specification of an authoring environment is very much with us today in the various hypertext systems that are available. At one level these provide very simple authoring tools; at a higher level they can provide sophisticated programming environments. Their very flexibility allows many of the objections to previous approaches to be overcome. It is still necessary, however, to maintain a focus on the educational aims and desired outcomes. The basic motivations for CAL have not changed, nor have the basic design requirements. Presentation of CAL materials should be orientated to producing the most effective learning outcomes.

1.6 Influence of Technology

So obvious is the need for a widely-available, low-cost, high-performance computing platform in the provision of modern CAL systems, that it is often overlooked. The general acceptance of direct manipulation interfaces, that is WIMP (Windows, Icons, Menus, Pointer) user environments, have eliminated much of the need for the language parsing of early authoring systems. This is not a thesis on general human-computer interaction, and so it is sufficient to briefly mention growth of such graphical user interfaces – from the early work on the **Xerox™ Star** system, the first major commercial exploitation through the **Apple Macintosh™** computer and the painfully slow provision of a satisfactory graphical interface for **IBM-PC™'s (Microsoft Windows™)**. Nowadays, no personal computer or workstation is complete without its graphical user interface.

All this is feasible because of the on-going advances in electronics components, for example, high-resolution monitors and custom circuits for the generation of graphical outputs, and the increasing power of computers and improved machine architectures. However, we must take care that developments are not solely technology-driven – that the user is presented with large screens of many windows, each packed with textual and pictorial information, a myriad of icons and an abundance of tools, simply because it is technically possible.

1.7 Hypertext

1.7.1 Introduction

Hypertext, was an idea first mooted by Vannavar Bush in 1945, who believed that since the human mind operated by associations, our machines in storing and accessing information should also. The term *hypertext* was first coined in the early 1960s by Ted Nelson. Hypertext, as an idea, had been waiting for the enabling technology ever since. It is, in concept, quite simple: windows on a screen are associated with records in a knowledge base and links (usually activated by a mouse) are provided to these records (see Figure 1.2). These records (information nodes or frames) are interconnected by links that are determined by semantic relationships that exist between the nodes. These links permit the user to explore the knowledge base in a non-linear and highly interactive manner. It is these user-activated linkages which form the essential element of hypertext; not just textual items may be linked, but also graphical displays, sounds, video, indeed any media which can be controlled by a computer. For such a plethora of material, the term *hypermedia* is usually reserved. It is also a requirement of a successful hypertext system that not only the concept is simple but also the implementation of that concept. This is especially important for educational use as materials should be easy to author (i.e., create nodes and links) by the subject expert/author, teacher or student, or combination of the three.

Hypertext has had a long history from the early seminal work of Bush (1945) to Nelson's **Project Xanadu** (1980) – but it has been the recent appearance of hypertext systems for small commonly available computers that has kindled the fire of this present enthusiasm. **OWL International** launched **Guide**™ in 1986 for **Macintosh**™ and in 1987 for **IBM-PCs**, and **Apple**™ released its own version **HyperCard**™ late in 1987. It was these that fanned the fire into an inferno – its horizons were unlimited, its use uncritical. To quote from one proponent:–

> It will allow "...the student's mind to explore and to follow paths that are not dictated by evident outside sources which permits learning in a whole new fashion. By allowing students to use the material presented in their own way and at their own level, with more difficult or advanced material invisible until asked for, hypertext brings a freedom to the educational process for both teacher and student that was not present before" (Kinnell, 1988).

The claim is that its non-linear presentation of information should enable students to view "the phenomena of the world in interrelated relativistic terms rather than as isolated bits of information" (Beeman et al., 1987). It is interesting to note however that the use of **Intermedia**™ (an advanced hypermedia system designed to support teaching and research in tertiary education) produced more significant learning effects on the people involved in developing materials than on the students using the system (Yankeovich et al., 1988). Nevertheless hypertext, especially in its realisation on commonly available computers, has given many teachers the ability to produce their own learning materials by means of extensive authoring tools. The success or failure of these materials still depends on the ability of the author. The possession of a computer painting package does not turn anyone and everyone into an artist!

1.7.2 Hypertext for learning

The case to be made for hypertext is that it promotes the acquisition of concepts – not isolated facts – in a manner controlled by the learner. As such it would seem to offer a basis for meeting some of our educational objectives. Adopting hypertext as an environment for learning has by-passed many of the previously encountered difficulties in effecting CAL, notably defining the student model and the learning processes. Responsibility for learning has thus been devolved to the learner who is deemed to have the necessary skill to affect successful learning. The role of the CAL system is then to provide the most appropriate conditions in which this learning should flourish. We should immediately note that our requirements for providing this environment, for example varied levels of control and support for a range of learning activities, would almost certainly require extensions to the basic hypertext tools.

The essence of hypertext systems lie in the provision of effortless navigation through knowledge bases. They are heavily dependent on the user accessing information in a meaningful and useful manner – this is particularly true for learning environments, since they often require more than the simple retrieval of information. Learning requires an active interpretation of the information and is "dependent on the stimulus attributes of the 'hyperspace' and the responder attributes of the user" (Fischer & Mandl, 1990). For the retrieval of information from databases, the navigational tools are dominated by the need for fast and efficient access. In learning environments, additional support tools are required to assist in the assimilation of new knowledge into the user's existing conceptual models.

1.7.3 Navigation and navigational modes

I wish to define navigation as the *activity* of moving through an information space – that is a sequence of purely physical events. Coupled with this definition are the various *navigational modes*; these are more conceptual and embody the role of the user's intentions and goals. Browsing, as an example, is seen as a navigational mode and not the physical act of navigation itself. Such definitions are not universal. For example, McAleese (1989) regards browsing as following hypertext links, with purposeful intent, and navigation as the use of specific *navigational tools* such as browsers, maps or other overview tools. I see browsing as an *exploratory mode*, akin to thumbing through a book to discover its likely breadth and depth from the contents pages, and extracting interesting snippets of information from the pages. Canter et al.(1985), in characterising user navigation through complex data structures, identify five navigational modes – scanning, browsing, searching, exploring and wandering†. The first four modes need to

† Their definition of browsing differs yet again. They define an exploratory strategy as discovering the extent of available information, and browsing as following a path until a goal is reached. These differences in definition are unimportant, it is the observation of different modes that is important.

be supported by the provision of suitable tools, and the last (i.e., purposeless and structureless navigation) needs to be discouraged.

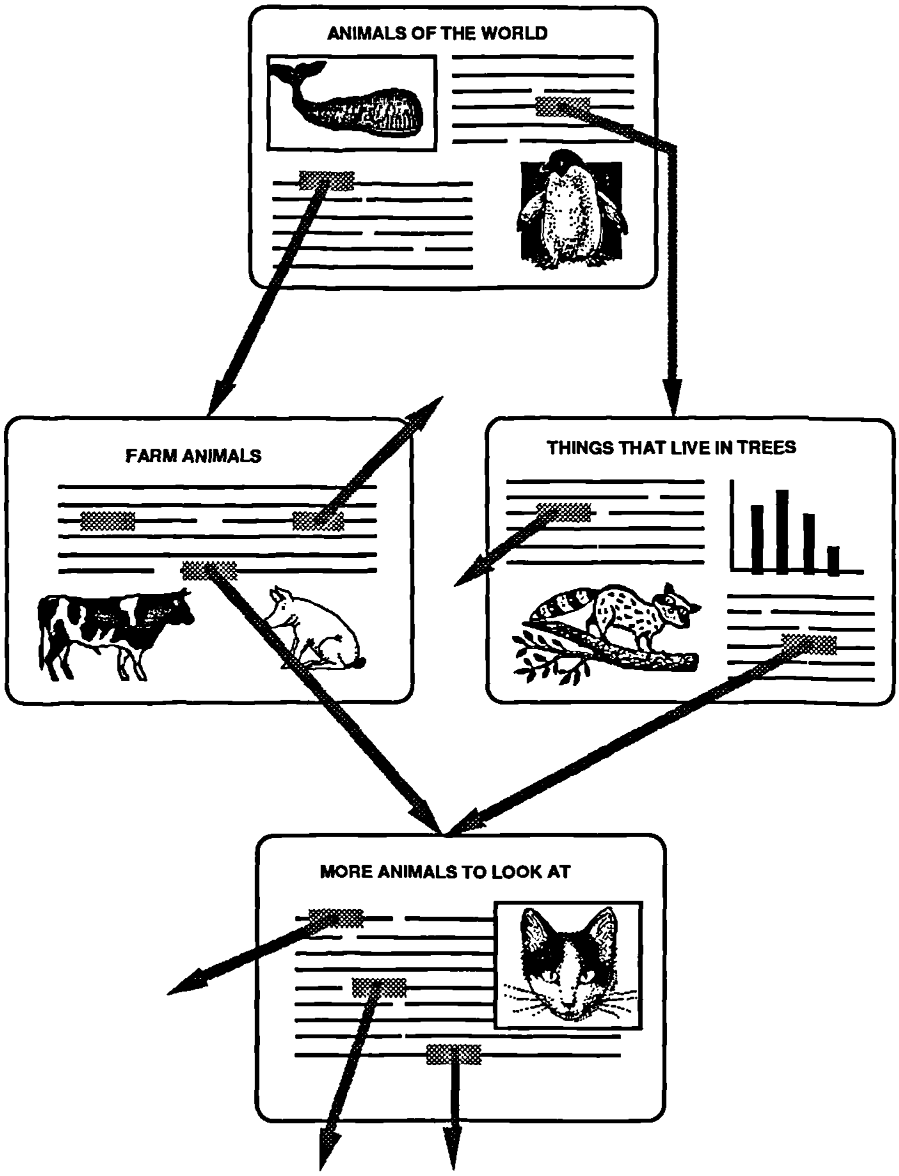


Figure 1.2 Illustration of hypertext – showing non-linear linkages between screens of information via user-activated links

1.8 Problems with Hypertext

However since the heady days of the early hypertext systems increasing criticism has been expressed over their usability. These problems can be delineated into two distinct but not disjoint areas – namely, disorientation and inefficiency (Allinson & Hammond, 1990; see Hammond, 1989, for a slightly different grouping). The next section introduces some possible problem areas and the suggestions which have been made to overcome them.

1.8.1 The disorientation problem

Getting lost in space (see Conklin, 1987) is likely if the learner is on unfamiliar ground in a possibly large knowledge database. The questions asked are "Where am I?" and "How do I get to some other place I know (or I think) exists?" Using a conventional text there is a similar problem, but the degrees of freedom are constrained to searching forwards or backwards through the pages. In hypertext the degrees of freedom can be vast – we really are in n-dimensional hyperspace! Two possible solutions have been suggested. The first is to restrict the degrees of freedom – to permit, for example, only a very limited number of links per information frame. Here, we are surely removing the very advantage of hypertext. It should be the inter-relationships between the knowledge nodes with determine the network not the requirement to present a simple user interface. The second is to provide various facilities for guidance. These have ranged from simple *backtracking* facilities to visual maps that show relationships between various knowledge nodes. Though we possess a highly developed short-term memory for visuo-spatial patterns, there is no guaranteed mapping of the knowledge space (perhaps multi-dimensional) onto a two-dimensional screen. Attempts to produce spatial maps of the knowledge base automatically (especially global ones) have produced a tangled web of links of meaningless complexity (Garrett et al., 1986).

The disorientation problem also means that some users fail to gain an overview of the knowledge base. They remain unaware of significant portions, or fail to understand how component modules relate to one another.

Other navigational tools that address the "Where is such-and-such and how do I get there?" are, for example, content pages, indexes and other logical search techniques. Some of these logical search techniques has been questioned by Glushko et al. (1988) who view browsing a table of contents or an index as preferable, since these are "... akin to a floodlight that illuminates the entire document, in contrast to searching, which is like a flashlight that shines brightly but only on a small part of the data." This efficient retrieval of information is ideal in some situations but not necessarily for meaningful learning. Learning is not determined by the rapid accumulation of facts but the slow and careful assimilation and integration of information into a coherent knowledge structure.

1.8.2 The efficiency problem

Students may wander about the knowledge base uncertain of their immediate goals, or perhaps they have explicit goals but are uncertain how to achieve them. Hypertext encourages investigation through a large number of links, but to someone who is lost, the presence of a multiplicity of paths is a distinct disadvantage. For the novice user this will certainly be the situation (Gay, 1986). Once again the number of links per information screen could be limited as a simple means of reducing choice. There is perhaps a maximum limit on the number of items for selection due to the problem of the cognitive-processing overhead. Mayes et al. (1990) argue that this cognitive overhead is inevitable given that following tenuous paths is at the very heart of hypertext. Problems of cognitive overhead are common where complex knowledge manipulation and integration are required. However, an environment that encourages these processes may well be essential in order to acquire a rich understanding. It may well be necessary to concentrate on several tasks or trails through the knowledge base at one time. As Spiro et al. (1987) state "... reading topics in expository texts is like choosing a path through a landscape ... in order to know the landscape one must take alternate paths through it and explore it from different perspectives."

It would seem that we need at times to encourage serendipity, and at other times to discourage it. Novice users, or even expert users in an unknown part of the knowledge base, will need extra guidance – to be led rather than to lead. Exploratory learning may not be appropriate in all circumstances. Jaynes (1989) claims that readers do in fact want to be led:–

> "...we cannot help but pity the reader who is told to 'enter and explore' to locate the answer to his problem; much more than being 'lost in hyperspace' he may actually be in danger of the paralysing vertigo that is said to afflict astronauts engaged in extravehicular activities when they confront the endless depths of space that stretch beyond comprehension in all directions. 'Enter and explore' is a condemnation, not a solution."

Whatever the pedagogical implications of such a stance it could be envisaged that there are appropriate times, either goal-dependent or user-dependent, where the learner would benefit by relinquishing his usually high level of control. *Tours* provide suitable supporting navigational tools. A tour presents to the learner a sequence of the key information of a particular portion of the knowledge base (as prescribed by the author).

In summary, there is the need for a wide range of navigational tools to help overcome the disorientation problem and to alleviate the inefficiency problem and support the various navigational modes. Hence, we need to provide a variety of *navigational tools.* These tools aim to locate specific information (e.g., indexes and maps), help structure bodies of information (e.g., guided tours, browsers, maps and folding) or help the user keep track of their movements {e.g., back-tracking, replay facilities, footprinting, bookmarks (Benest, 1990), and personal browsers (Monk, 1989)}. Where cognitive overload may well present a problem for users is in the use of these additional tools or specific mix of tools. This is where interface issues are important. The correct mix of facilities needs to be provided in an interface such that its operation remains essentially transparent to the user. We should attempt to ensure that the user learns to manipulate the information base and not the system.

1.9 Hypertext and Hypermedia for Learning

It is perhaps not surprising that such an impact was made by the arrival of hypertext systems on CAL. Hypertext systems place the responsibility for accessing, sequencing and deriving meaning from the information clearly with the learner. This added responsibility on the learner both for sequencing and cognitive processing of the information would appear to be consistent with the constructionist conception of learning. For the designer, it is a release from the hitherto unresolvable problem of the learner model. For the educationalist, the advent of widely available, cheap authoring systems meant that software could be easily produced, with apparently little more expense (i.e., time, skill and cost) than with conventional tutorial materials. As such bold claims have been made for the use of hypertext, it is worth exploring these in more detail.

It is suggested that the semantic structure of the expert's knowledge, as represented by the hypertext, can be mapped onto the semantic structure of the learner's knowledge. During the process of learning the learner's knowledge structure is believed to increasingly resemble that of the instructor's (Shavelson, 1974; Thro, 1978). Jonassen (1986, 1990) presents cognitive principles based on learning theories that may make hypertext designs valid for instruction. Despite an inherent appeal there are problems with this. Firstly, do we want to impose the *expert* structure on the learner? This may detract from the basic argument for hypertext in that it opens up a knowledge domain to the learner. It may, in fact, constrain the learner to this particular *expert* view of the subject. Secondly, the idea that hypertext "matches human cognition", particularly the organisation of memory as a semantic network of concepts linked by associations, is clearly not the case as it could never resemble the complexity of human memory with its richness of semantic associations developed across a life-time of experiences. Whalley (1990) makes the point that the simple graphs of typical hypertext, with their relatively large information nodes, is really very different from the complex, fine-grained semantic networks of the individual's own knowledge base – with its rich contextual significance. A further problem with the sole dependence on semantic structure to convey understanding is one of scale. Semantic links alone may be effective in giving an overview and understanding of a conventional hypertext consisting of relatively few nodes, but are inadequate for large-scale systems (Frisse, 1987). From a learning theory perspective, hypertext should improve learning as it focusses attention on the relationships between ideas rather than on isolated facts. The associations provided by links in the hypertext database should facilitate remembering, concept formation and understanding. Doland (1989) claims that meaning arises as a function of structure. By structuring hypertext according to the multiple perspectives generated by a semantic model approach, meaning can be generated by the user who is searching for it (Verreck & Lkoundi, 1990).

Beeman et al. (1987) suggest that hypertext usage encourages non-linear rather than linear thinking and hence stimulates processes of integration and contextualisation. We can also question this second claim. Duffy & Knuth (1990), for example, believe that it does not. They believe that one of the major problems with hypermedia is in "... maintaining the big picture – maintaining a sense of the complexity of relationships". They go on to claim that it is the various overview techniques and not the hypertext links themselves that promote the non-linear thinking.

If we are to understand the effective use of hypermedia as a database to explore, we have to understand the nature of the explorations and their task-driven goals. Whatever the particular hypertext implementation, its potential is only realised in the learning goals that the learner brings to the interaction. What is learned in using a hypertext is dependent on both why and how it is used. The student will develop understanding based on evidence gathered during completion of their tasks. It is unlikely to be a replication of the hypertext database structure itself but an abstraction, re-organization and construction of knowledge based on a subset of the database. This re-organisation will be determined by the particular learner goals, and the information integrated by the learner into their own knowledge structure. This integration occurs as the learner formulates their own links to their existing knowledge structures. If the assimilation of information from a hypertext is not to resemble rote learning, then what occurs is the formulation of new semantic structures or organisations and not the acquisition of the semantic knowledge structure of the expert. This view is very much in line with the constructivist learning theories outlined earlier in this Chapter.

Whether or not the semantic links themselves do have a role to play in aiding both knowledge assimilation and non-linear thinking has yet to be tested. But if we no longer accept the need to adhere to a fully semantic relationship between nodes and active exploratory learning and the need to maintain this structure in its entirety, we are in a position actively to promote the use of various navigational facilities within a learning environment. Holding strictly to the view that we inherit the *expert* structure of a hypertext, we find it more difficult to justify certain of these additional navigational facilities on pedagogical grounds. Various access facilities cause varying levels of disruption to the semantic or conceptual models employed by learners. Edwards & Hardman (1989), for example, argue that the provision of an index facility impairs the user's ability to form conceptual models of the information domain. Similarly, Simpson & McKnight (1990) found that users provided with hierachical contents lists produced more accurate maps of the hypertext structure than those provided simply with indexes. These authors agree with the findings of Mahoney (1988) that a mental map of the text structure is essential for efficient navigation. McKnight et al. (1990) conclude from empirical studies that browsing is restricted in the hypertext condition as opposed to linear presentation as the time taken jumping to and from an index leads to superficial reading of the information and less accurate retrieval. Linear pathways (i.e., tours), will similarly negate the advantages of hypertext's basic non-linearity. It must be emphasised here that most of these studies were of information retrieval rather than learning and presented different implementations of the index facilitities (e.g., indexes and content lists as used in the Simpson experiment are useful only for information provision and not navigation). Navigation using the least number of mouse-clicks or key presses, may well be important indicators of information retrieving efficiency but different criteria and metrics will apply for learning.

The importance of the mental model itself may vary according to the information presented in a hypertext, the task undertaken and the user goals. McKnight (1990) claims a clear model of text structure exists for readers of journal papers, hence, hypertext presentation of these should not be of a radically altered format. The issue this raises is whether the mental model itself is necessary (clearly it is for reading a journal paper but what of information of which the learner has no knowledge or preconceived structure) or whether the requirement is that a user's existing mental map should not be disrupted. Further issues relate to the form a mental model may take. Some workers clearly disregard the need for a clear network model based on fixed links. The

Strathtutor system, for example (Kibby & Mayes, 1989), can be viewed as a dynamic hypertext system as linkages are generated at runtime. As no physical network exists "... browsing is encouraged to take place in conceptual space, rather than in the spatially arranged network of conventional hypertext" (Mayes et al., 1990).

What can be seen is that issues of navigation, task, and knowledge domain are closely intertwined, and interaction effects are likely. Yet a fourth component in this interaction is that of the learners themselves, which adds yet another level of complexity. Different learners may approach their tasks in different ways, and indeed interpret their goals differently dependent on factors such as motivation, inherent styles and strategies for learning. Although these user differences are important they will not be discussed here, but a detailed review will be presented in Chapter 6. User behaviour becomes a central issue in using hypertext as such systems can be viewed as active environments by providing a high level of learner control – the user being actively responsible for their own progress through the knowledge domain. The amount of learning activity undertaken will be determined by these user-centred components. However, the prime role of any communication medium must be to engage the learner. First and foremost it is essential to provide a good interface coupled with the provision of the correct navigational tools with which to pursue the learning in order to enhance the usability and usefulness of these systems. Many proponents of active hypertext however would advocate going beyond the provision of navigational tools, to the provision of tools for generation of new information (nodes) and the creation of new relationships (links). The active learning environment can be extended still further to provide collaborative learning environments. These issues are basically ones of authoring and have important implications at all levels of implementation. The provision of various learning tools such as concept mapping facilities together with note-taking and annotating facilities can also be important elements in a learning environment, but their discussion will not considered here. The main emphasis of this thesis is on the provision of the correct mix of navigational tools embedded in an understandable and usable interface.

1.10 Outline of Research Objectives

As stated at the beginning of this Chapter, the primary purpose was to develop a CAL system to assist in the teaching of some aspects of cognitive psychology. We were, in 1986, when this study was initiated, ignorant of much of the early research work on hypertext systems and certainly there were no commercial systems available. It is interesting, with hindsight, to see how our design decisions – formed in isolation – resulted in a system implementation that bore such close resemblance to the commercial systems that have appeared since. Our starting point was that the learning process is complex and not understood in detail, that students would bring with them as they commenced to use our CAL system a diversity of learning styles and a diversity of needs. We did not believe that our system was a replacement of any elements of the conventional educational process (e.g., lectures, tutorials and practical classes), but that it was an additional supporting component. For this reason, we coined the term learning support environment (LSE). We saw the need for a rich variety of navigational tools to be provided that would meet the differing styles and needs. In essence, this thesis is concerned not only with the provision of these tools but with their use – by users with differing tasks and by users with differing learning styles – and the perception of the system and its tools by the users. Our early recognition that navigational strategies differed led us to attempt to identify some of the underlying reasons for this observation. In order to improve the transparency of the interface and to enhance the user's internal model of the system, we introduced the idea of an extensive metaphor to describe the system and its tools.

The evaluation techniques applied in this thesis are, in the main, concerned with collecting data from log-files, that record in fine detail the actions of individual users as they navigate around the material, and from questionnaires. This is because we are primarily concerned with the use of the navigational tools for a wide range of users – with differing tasks and differing cognitive styles. The relatively large number of subjects required for this approach prohibits the use of in-depth study techniques. In-depth study techniques, if applied only to a small number of subjects may have resulted in a failure to identify the full variety of usage styles that may exist. We, also, wanted as far as possible to present as naturalistic environment as possible. During prototype development of the system, in-depth interviews with individual users were employed.

1.11 Outline of Thesis

The cognitive principles, that were the foundations of our learning support environment – namely, the Hitch-hiker's Guide – and the manner they were incorporated in the implementation of the system, are described in Chapter Two. The function and implementation of the system metaphor, which in our system was based on a travel holiday, are also discussed in this Chapter. A functional description of the Hitch-hiker's Guide is presented, together with details of the early user testing.

Chapter Three is a detailed account of the implementation of Hitch-hiker's Guide for a computing platform consisting of a network of IBM™–type personal computers. Though in no way is this the complete formal software documentation, it is quite extensive. This Chapter, also, contains a functional description of the authoring software developed to support the production of learning material for Hitch-hiker's Guide. Brief details are given concerning other utility programs developed.

Chapter Four describes the first "real full-scale" application of the system – namely, its use in supporting cognitive psychology courses for undergraduate students. Several questions were posed at the commencement of this stage – what did the users think of the system? what did the students use it for? did they make use of the navigational tools provided? The answers were both encouraging and incomplete. The totally voluntary use of the system by the students and their comments from questionnaires demonstrated that it fulfilled a need. Though most students used most of the navigational tools, we were ignorant of their specific requirements of the system at any particular session. This Chapter, also, describes the system modifications that were made as a result of this extensive use by the students.

Part of the variability in the use of the system, in particular the differing styles of navigation through the information base, is due to the differing needs of the individual students – from general browsing to specific searches for isolated facts. In order to examine the effects of task on navigation, a set of experiments was conducted on a group of novice users. They were given with prescribed tasks and sub-groups were provided with systems, which possessed differing navigational tools. Chapter Five describes these experiments, and discusses the differences in system use as a function of task and available facilities. Again, not all the variability can be related to task. Some, it was thought, was due to variations in learning styles among the users.

A discussion of cognitive styles and strategies is presented in Chapter Six. Though many such styles have been suggested, the work has concentrated on employing a robust, and widely used, method of differentiating prospective users on the basis of their differing learning styles. For these reasons Noel Entwisle's Attitudes to Studying Inventory was chosen. The justification of and findings from this inventory are presented. A questionnaire survey of 310 university students was conducted using this inventory. The results are described, in particular those for uncollapsed questionnaire data factor analysis. Comparisons with the findings of other workers are given. Finally, this

Chapter describes the means by which the subjects were selected for the final experiments.

In order to examine the effects of the user's learning style on system usage, a final set of experiments was conducted. These are described in Chapter Seven. This time the learning task was made substantial (learning a coherent body of complex information), as was the subsequent testing. Subjects were given a preliminary session, so that the observed navigational techniques were more those of an expert user than a novice one. For these experiments, Hitch-hiker's Guide was implemented in **HyperCard™** on **Macintosh™** computers. The relationships between system usage and learning style are presented and discussed.

Finally, Chapter Eight brings together the results of all these investigations, and discusses their significance for future CAL system design.

CHAPTER 2

DESIGNING A LEARNING SUPPORT ENVIRONMENT: THE HITCH-HIKER'S GUIDE TO COGNITION

2.1 Introduction

To reiterate, at the start of this project our primary goal was the provision of an innovative and useful software package to enhance the teaching of a cognitive psychology course module within the Department of Psychology. Secondary goals, however, were to use the development of this software package both to draw on and to enhance our theories of interface design and elucidate our understanding of the requirements for an appropriate educational framework for effective CAL materials.

Our motivation was to promote both flexibility and freedom. One basic assumption was that learners, especially those in tertiary education, can benefit from control over their learning or at least over where control should reside. They have metacognitive learning strategies. So it is they, not the program, that choose the best patterns of interaction to ensure maximum facilitation of learning. We did not wish to channel their interactions through narrow paths as we saw to be the case in much of the existing software or provide a too limited content (once again a common limitation of many hand-crafted programs). These would restrict its usefulness. Flexibility was also required to cater for the varying needs of our student population. Just as one might open a book and interact with its content in a number of different ways (e.g., skimming to gain general impression, read from cover to cover for in-depth study, or search for specific information), it was important to provide a facility that would not be restricted to specific user requirements and motivations. In our design, we need to differentiate between user tasks and user learning styles.

Our aim was not to emulate a book, but to capitalise on the best and most applicable aspects of printed text and yet utilise the computer to full advantage – within the context of known educational and psychological theories and the currently available technology. The book metaphor is, in part, a good one in at least describing the breath of coverage of the knowledge domain that we envisaged. In some ways we wished to produce an *electronic book* of the course, but the metaphor breaks down in that we did not feel that it was desirable to present material on the screen in the same depth as we would in a textbook. The computer is not the most appropriate vehicle for the presentation of large amounts of text, despite recent rapid advances in display technology. We cannot hope to compete with the current capabilities of print but we can complement our more limited text with the current *capabilities* of computer technology. We needed to capitalise on the dynamic functions afforded by the computer, the immediacy of access, the flexibility of presentation, the potential of animation and the ability to mix together these various forms of presentation. So that the resulting *integrated whole* provides more for the learner than would the sum of its parts.

We must be cautious that design is not purely technology-driven either in its conception or development. In our project we were both fortunate and unfortunate in that our chosen hardware base of the **Research Machines™ Nimbus** computer offered, at that time, excellent graphics capability for a machine aimed at the educational market, but its non-compatibility with **IBM™** graphics standards meant that existing authoring packages could not be used. It should be emphasised that the authoring systems available at this time were not hypertext systems but were those described in Section 1.5.3. Difficulties in obtaining the necessary information on file formats made existing paint packages hard to utilise. We were hence left with basic software tools (e.g., a Pascal compiler and text editors) and the freedom to implement a system purpose-designed to our own requirements – utilising our knowledge of the available educational, cognitive and interface design theories. In hindsight, it was providential in that we did have an opportunity to produce a system that not only met our requirements but also addressed many of the problems that were materialising in the application of hypertext systems that were developing in parallel with our work.

This Chapter discusses the context in which our learning support environment was designed, the underlying cognitive principles and the functionality of the realisation. A number of pictures of the system are included in order to provide an impression of the final product. The use of a general metaphor to aid the user's model of the system's capabilities is also discussed.

2.2 Educational Context

The basis of system design must be the formulation of a clear set of requirement specifications. For example, it was important to take account of the educational context in which the computer-based learning would be required. It was also necessary to have some model of the *typical* user (or range of users); for example, an understanding of the user's existing domain knowledge, computer skills and learning motivations. Our own philosophy, based on a review of the available literature and the existing systems, was to provide a learning support environment (LSE). An LSE is an environment designed to support the user in their own search for knowledge and understanding and is not intended to replace conventional lectures or extensive reading of the literature, but to supplement these lectures and act as a springboard to further reading and study. Hence, it integrates into the traditional educational environment of a University. Users are liable to have some basic knowledge about the domain material before exposure to the system. However, the users' existing knowledge base will vary considerably as will their requirements of the system (e.g., initial exploration of a topic, preparing for an essay or examination revision) and their individual learning strategies. The system needed to be flexible in controlling both the sequencing of the learning materials and the types of learning activity. Traditional approaches to CAL present little in the way of control over the sequencing of the materials and nothing in the control over learning activities (see Section 1.4). An archetypal hypertext system can provide great flexibility over the sequencing of the material but without the provision of overlying navigation tools, it can do little to assist the varying learning strategies of individual users. Indeed the very flexibility and freedom afforded may hinder the user. Users may get lost or at least experience difficulty finding specific information. A specific problem is that users may ramble through the knowledge base in an unmotivated and ineffective fashion, unable to forge the links between the individual information screens and so discover the underlying concepts that hold together and structure the isolated knowledge *fragments*. It is this matching between the learner's needs, abilities and strategies and the optimal level of control that we have attempted to address in the design of the **Hitch-hiker's Guide**.

2.3 Psychological Principles and Educational Objectives

The psychological literature concerning learning is vast. An overview of selected educational theory was given in Chapter 1. Further principles are elucidated here. Little of the work has been considered within a computer-based environment but we can isolate some of the main underlying principles that have driven our design efforts.

- **Encoding specificity** – Material can be recalled if it contains distinctive retrieval cues that can be generated at the time of recall. The relevant work of Tulving on encoding specificity is discussed in the next Section.

- **Encoding variability** – Multiple exposure to the same material in different contexts will result in easier recall since the varied contexts will result in a greater number of potential retrieval cues. This variability is, of course, related to encoding specificity and also is discussed in the following Section.

- **Knowledge assimilation and integration** – We build up our knowledge base by attaching new information to an existing knowledge structure and make constant minor alterations to this structure in order to accommodate this new information. Understanding and learning will be enhanced if students can relate new material to that which they already possess. Students should be encouraged to form these relationships and to develop frameworks for their knowledge. These ideas were discussed, mainly in terms of Ausubellian theories of learning, in Section 1.2.

- **Depth of processing** – In general, the more a student thinks about and explores the meaning of the material presented, the greater will be their understanding and memorisation. The importance of active over passive learning was also discussed in Section 1.2. A related aspect concerning active learning is the **enactment effect** – if subjects are required to carry out some activity rather than just read about it, their subsequent recall will be improved (Cohen, 1981).

- **Learner control** – There is a complex relationship between the learner, the learning materials and the learner's goals. Learners need control over this, choosing their own behaviour patterns to ensure maximum facilitation of learning. Learners possess metacognitive strategies concerning their learning styles. This need for system flexibility in assigning the locus of learner control was discussed in Section 1.4.

It is useful here to comment on those principles not discussed in the previous Chapter.

2.3.1 Encoding specificity and variability

The philosopher Wittgenstein raised doubts concerning the fixed nature of the meaning associated with any entity (Wittgenstein, 1953), claiming that meaning was dependent on the context in which it occurs and in fact varies from context to context. Tulving & Thomson (1973) extended this idea and developed the notion of variable conceptual mapping of conceptual meaning into a feature-oriented model of information content in memory. For example, consider a general concept such as *cattle*. Within the context of being chased by a bull (it should be noted that context refers essentially to a meaning context rather than a physical one – and the current example is only illustrative), then we are likely to code the cattle concept in terms of features such as *is dangerous*, *gets angry*, *has horns*, etc. While watching a cow gently chewing its cud, the cattle concept might be *docile*, *gives milk*, etc. The idea of variable codes reflecting the same entity, when encountered in differing contexts, is termed *encoding specificity*. During the course of an extended series of experiments Tulving and his co-workers were able to report data that clearly supported the view that the presentational context plays a critical role in determining the success or failure of subsequent recall (see Howes, 1990, for a review of this work). It should be noted that the majority of experiments that have been performed concerned simple word-property associations. It may not be possible to apply the findings to the more complex learning situations encountered in tertiary education. A distinctive context may impose an organisation of the information in memory that can aid the retrieval process if some of these distinctive contextual cues are presented in the subsequent examining situation.

When information is presented on multiple occasions then their encodings into memory will be slightly different on each occasion. An obvious factor influencing the differences in learning context is that of time (it is an easy variable to control in experimental situations). The importance of the spacing effect (i.e., the number of intervening words to be learnt in a word list) on recall was studied by Madigan (1969). The basic finding is that recall improves as the spacing between presentations increases. A variation of these experiments indicated that varying the context in which a word was presented (i.e., paired with the same word or a different word on each presentation), resulted in recall being enhanced for the *different word* condition. This process of elaboration increases the number of contextual cues between learning and testing and so increases the redundancy of interconnections among the subject's knowledge base. Anderson (1985) summaries these findings as follows:–

> "The encoding-variability analysis of the spacing effect does not imply that spaced study and variable encoding will always result in superior memory. What is really important is that one of the contexts in which the material is studied overlap with the context in which the material is tested. When students are not sure how the material is to be tested, they should study it in contexts as varied as possible."

2.3.2 User differences

Different students, or the same students with advancing familiarity with the material or with differing needs, will adopt different learning strategies. This has been suggested in the serialist-holist dichotomy of Pask & Scott (1972). Students can also vary in their approaches to study, they may exhibit characteristic *deep* or *shallow* processing, or be *strategic* (pragmatic) in their approach (Entwistle, 1987). The student's approach may well be changed by the importance they place or interest they have in the current task. Individual differences and their importance are dealt with more fully in Chapter 6 and will not be discussed further here. What is important to note at this point is that the design of an LSE must cater for these differences in students and their goals.

2.3.3 Realisation

To capitalise on these underlying principles would require the following system features:–

- Distinctive and multiple forms of representation provided by the use of graphical and dynamic presentation. These support the user's encoding strategies.

- Rich access structure with many cross-links for integration. Again this supports encoding strategies, and the integration of knowledge.

- Ability to juxtapose materials to help integration, for the support of knowledge assimilation.

- Dynamic models, interactive demonstrations and multiple-choice questions to stimulate active learning. These assist in strengthening the enactment effect.

- Multiple navigation methods to provide flexibility in learner control.

Naturally, all these need to be provided within a simple user-interface in order to aid quick comprehension by users of the system facilities. These features are intended to capitalise on the psychological processes involved in learning and provide us with an environment for learning that attempts to meet many of our educational needs and goals. To realise these design principles, an LSE based on a direct manipulation interface, driven by a mouse, was considered to be most appropriate. This formed the basis of what later came to be regarded as a hypertext system.

2.4 Realisation of a Learning Support Environment

2.4.1 Introduction

Our hypertext system – the **Hitch-hiker's Guide** – is a realisation of our concept of an LSE. Our goal was to provide the learner with a set of navigational tools to support learning, within the specified context of university-level psychology teaching, for a variety of tasks (i.e., supporting lectures, essay preparation, revision), different levels of user knowledge and different learner strategies. Our aim to ensure flexibility and freedom led to the implementation of various system features Our experiences during the early system design and prototyping highlighted the potential problems with this total freedom and flexibility for the user, and led to the implementation of new, or refinement of existing, system facilities. An example is the tour facility and the metaphor within which the tour and, indeed, the system functionality are embedded. Evolution of the system occurred over a period of time as feedback from early system usage resulted in continued modification to the basic design. We have been mindful of the potential problems highlighted during this period and hence the system has been subjected to evaluation and testing over a lengthy period of usage.

2.4.2 Design of the authoring system

Armed with our educational aims and psychological principles, we were in a position to specify our prototype LSE. This first entailed the design of the authoring component (called **PED**), which permits the teacher to define a large network of display frames (implementation of this program is given in Section 3.10). The authoring system will receive little attention here as it is the presentation system (called **LINKER**, see Section 3.4) that is the vehicle for the delivery of CAL materials to the learner. The majority of current hypertext systems combine the functionality of these two components. Nevertheless, the design decision to provide an authoring environment rather than to *hard-code* the knowledge frames was a significant one as it conferred flexibility on the system. **PED** and **LINKER** have been employed for different knowledge domains (for example, from the cognition materials to the 'York Guide'), by different authors and for widely differing presentation purposes from its use in tertiary education to its application for the testing of autistic children using an animated version of the Sally-Anne task (Swettenham, unpublished thesis). Giving control to authors permits them to specify both presentation mechanisms (e.g., use of animation), and the nature and combination of mechanisms that are made available to the users for accessing the information frames. The rest of this chapter will discuss design features as seen from the perspective of the presentation software, but it should be borne in mind that the features provided (e.g., animations, data collection, and quizzes) have been generated with the use of our authoring software and its accompanying utility programs. Our chosen set of educational objectives and cognitive principles imposed constraints on the author that were not inherent system constraints. For example, our design for the **Hitch-hiker's Guide** was to leave choice with the author, in that there are no restrictions imposed over the use of mouse-selectable areas or the available navigation mechanisms. The authoring system could have easily allowed for a linear presentation or a presentation that branched dependent on user action. This flexibility of the authoring system permitted easy manipulation of the interface and its functionality for prototype testing and evaluation studies. But it must be said that the success of the system depends in large part on the expertise, skill and flair of the author in creating the materials.

2.4.3 The interface

The user interface is entirely mouse-driven, and each display frame consists of a main display area with a variable number of mouse-selectable areas (termed *active areas*). These define *hypertext links* to related frames, which are traversed by *clicking* over the selectable area. The position of the mouse is indicated by a cursor, normally an arrow shape (i.e., ) but if the user is on a *guided tour* (discussed later) then the cursor takes on the form of a small coach (i.e.,  – visible in Figure 2.13).

2.4.4 Ease of use

Many candidate user groups, including our target undergraduate psychology students, are not generally proficient at using computers. Indeed, our own students are often further alienated through their early interaction with various statistical packages which bear all the hallmarks of a traditional mainframe interface. If the voluntary use of an LSE was to be successful then the system needed to be productive in extending the student's knowledge and understanding. The system needed to be easy to use so as not to squander the student's resources on learning the system *per se*.

2.4.5 Transparency

Computer systems possess many layers. We will not concern ourselves with the internal physical levels of operation but consider, briefly, the layers of abstraction available in a software application. Traditionally in navigating around some knowledge base, the user is required to invoke explicit instructions – a command line interface. They have no need to understand the underlying data structures or functions employed. Hypertext removes the user one level further away from the physical layers. They are allowed to work more in the task domain than in the system domain. In order that they can form a model of the system, and hence appreciate its capabilities and limitations, the idea of metaphors has been employed, sometimes unconsciously, by designers. Metaphors may be restricted in their range of application, capturing only a few characteristics of the system. For example, in Unix, a subset of commands and facilities are described in terms of a hydraulic metaphor involving *pipes* and *tee-pieces*. Other metaphors are of a much wider scope in that they attempt to encompass all, or much, of the functionality of a system – for example desktops or electronic books. Such metaphors can be considered as yet another level of abstraction.

The use of metaphor is seen as a means of improving the transparency of the interface, of assisting users to navigate successfully around complex systems and of providing a partial mapping of the knowledge domain. A metaphor is an analogy, in that we attempt to improve another's understanding of a situation, which they have not experienced, by comparing it with a situation which they have experienced. Learning by analogy is a basic form of learning. Carroll, Mack and Kellogg (1988) discuss approaches to and implementations of metaphors in user interface design. Further aspects in the use of metaphor, and their role in system design, are given in Hammond & Allinson (1988). For the **Hitch-hiker's Guide**, we employed the general metaphor of a *Travel Holiday*. It is convenient to think about structured information in spatial terms. For example, we indicate the hierarchical structure of information or data by constructing trees and graphs. Travel therefore appears to a promising device. Within this metaphor, each information screen becomes a place to visit and the various navigational facilities as ways of travelling around these places. Section 2.6 will discuss how the system facilities discussed in the next Section may be mapped onto this *Travel Holiday* metaphor.

2.5 Issues in Presentation Design

2.5.1 Interactivity

Use of a hypertext system is inherently interactive, and student control over this interaction will naturally tend to promote active rather than passive learning. It also promotes understanding from different perspectives. To enhance this interactivity multiple-choice quizzes, interactive demonstrations and experiments are included where ever appropriate. The system is capable of interpreting user activity and hence of providing conditional branching to different frames, and displaying the results of experimental or quiz performance in the form of either numerical data or graphical representation.

2.5.2 Colour and graphics

The use of both colour and graphics has allowed us to create information screens that are both distinctive (in order to aid recall) and functional. Colour has been used in the **Hitch-hiker's Guide** to denote both type of screen (e.g., information, quiz and index) and also to detail functionality within a screen (e.g., to denote mouse selectable areas and to provide footprint information as on map screens). Our colour convention is to use yellow text for selectable areas (see Figure 2.1). **Hitch-hiker's Guide** can display both object-orientated graphics (generated in the authoring facility) and also bit-mapped graphics as illustrated in Figure 2.1.

2.5.3 Use of animation

Animation is used to enhance the otherwise static nature of both text and graphics, and to provide stimulus material for various experiments. Figure 2.2 (a-d) show a sequence of screens used to explain a particular model of attention. Figure 2.3 (a-c) show a sequence of screens where another attentional model itself is animated in order to simulate the threshold model for a particular stage of processing. Care must however be taken in the use of animation in order to provide the correct time delays so that information is presented at a rate that is not too fast to assimilate, or too slow to frustrate the learner. Hewitt (1987) advocates user control of the presentation rate whenever possible. Naturally, for certain demonstrations within the cognitive material, for example demonstrations of focussed attention or of Sperling's iconic memory (Sperling, 1960), timings must necessarily be prescribed by the author.

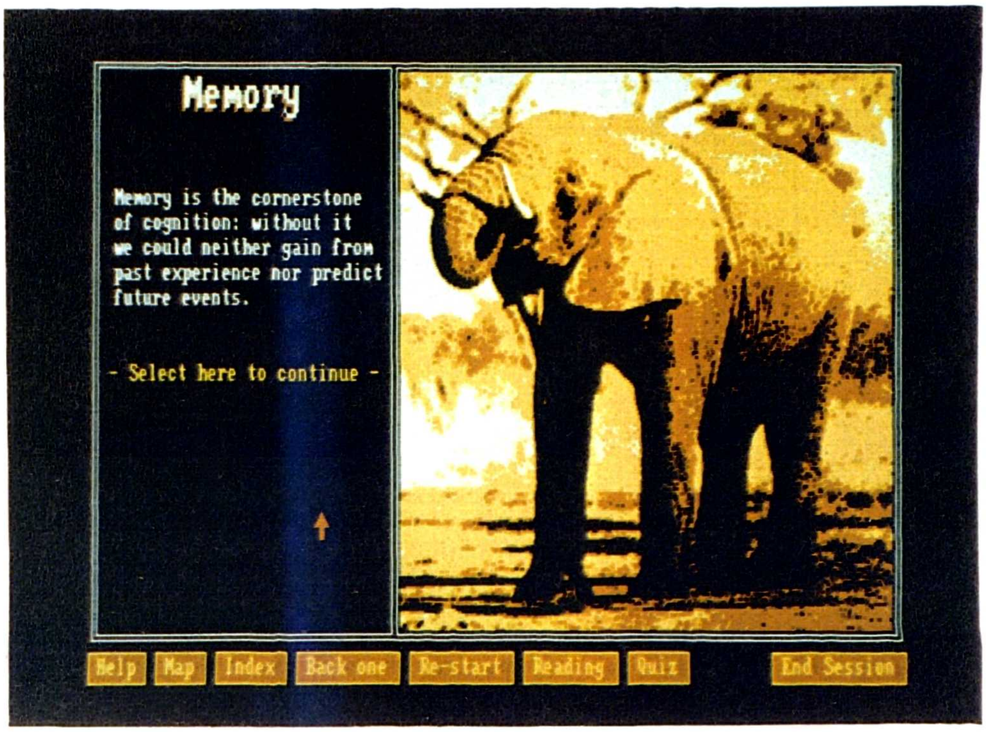


Figure 2.1 *An example of bit-mapped graphics and mouse-selectable text*

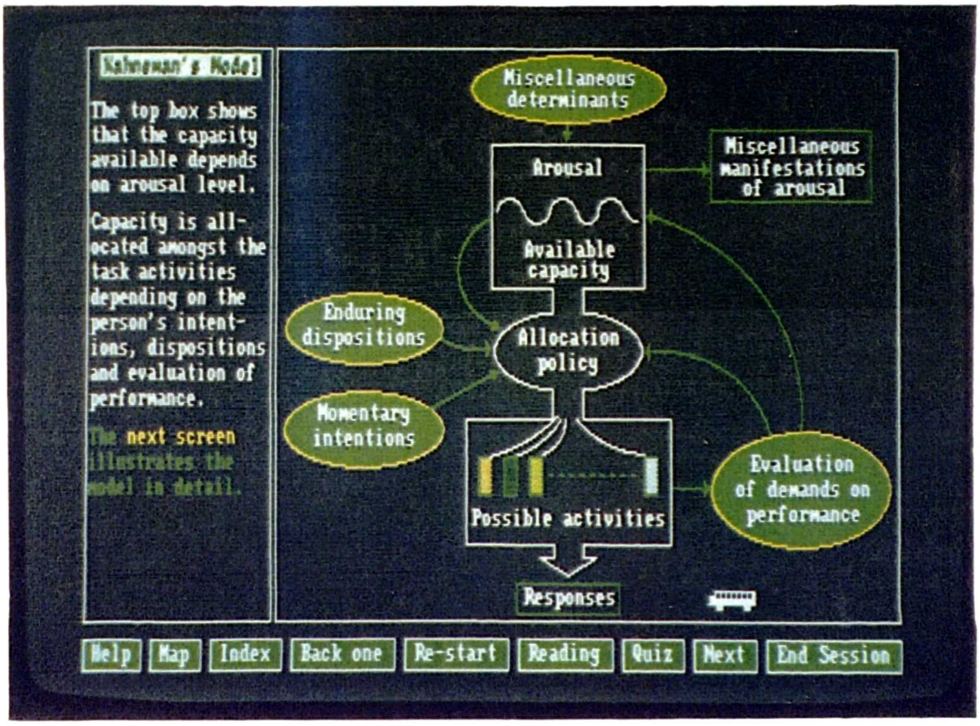


Figure 2.2(a)

Figures 2.2(a-d) Sequence of animations designed to explain Kahneman's model of attention

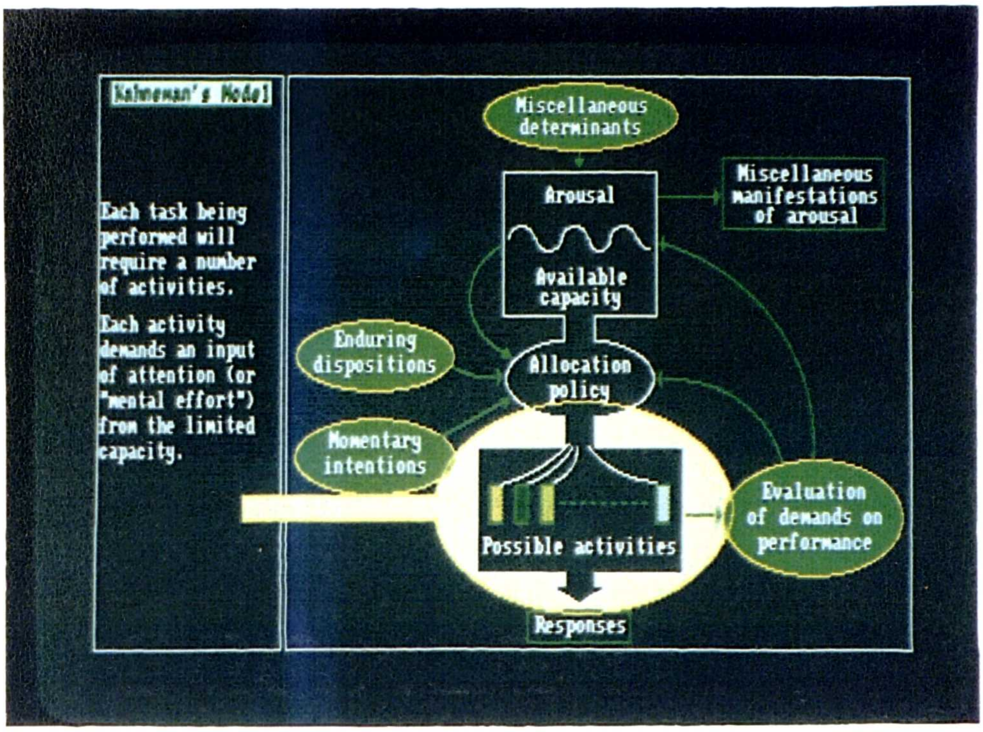


Figure 2.2(b)

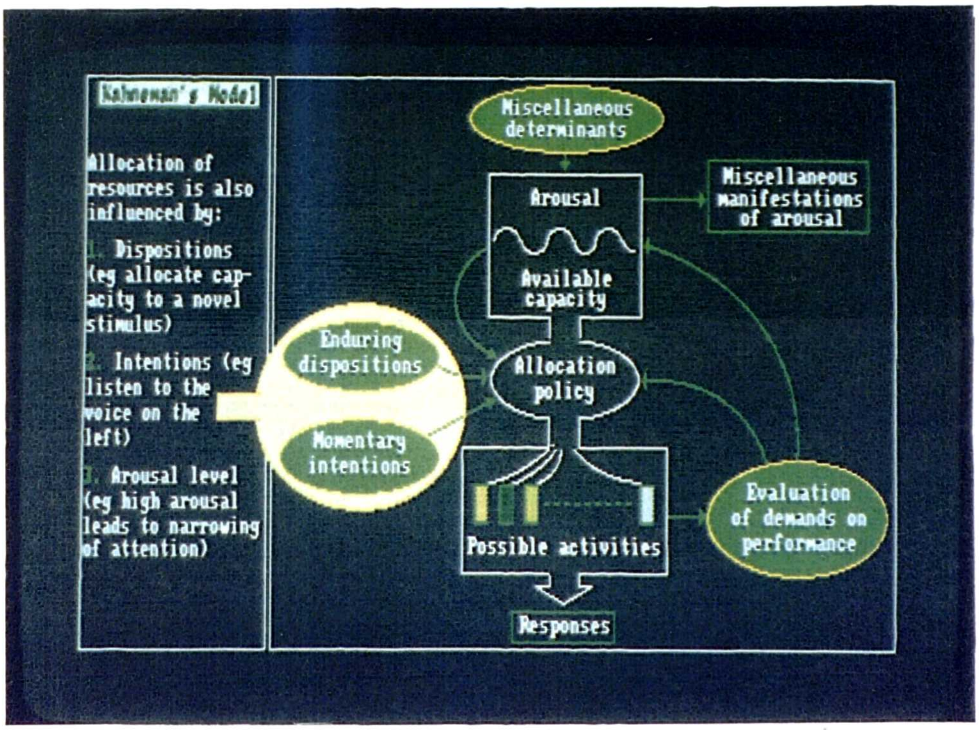


Figure 2.2(c)

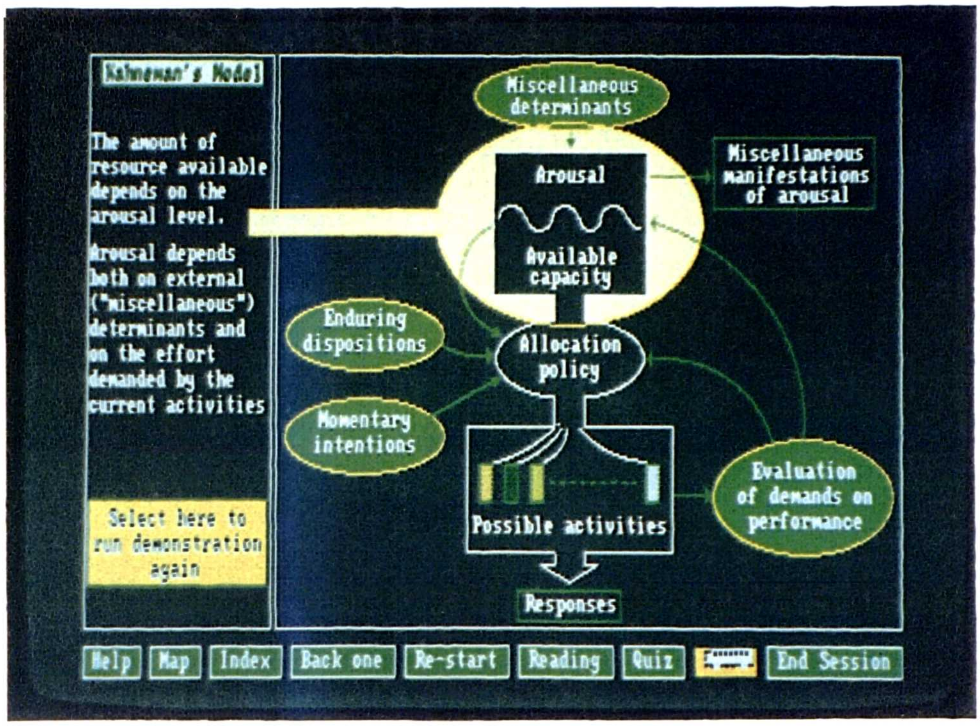


Figure 2.2(d)

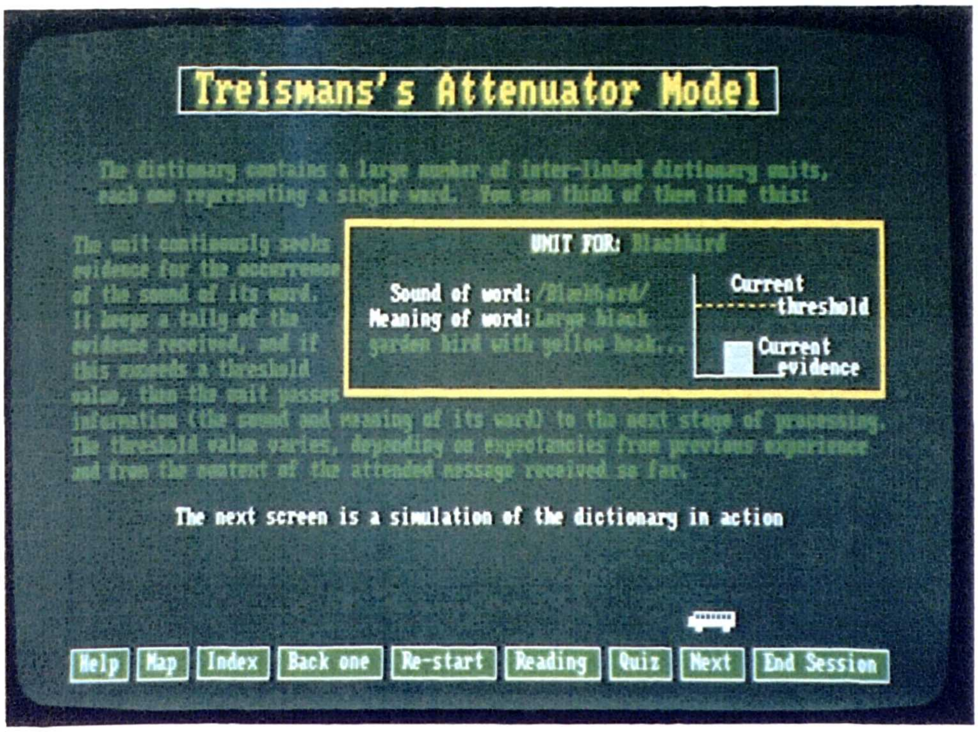


Figure 2.3(a)

Figures 2.3(a-c) Sequence of an animated model of Treismans's attenuator model (Treisman, 1964)

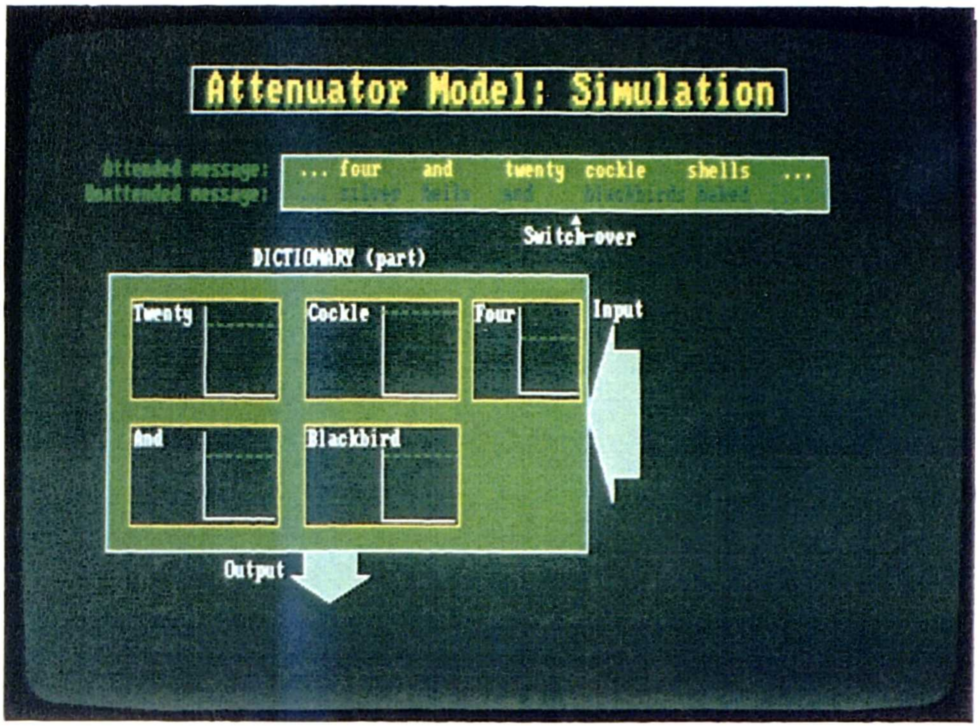


Figure 2.3(b)

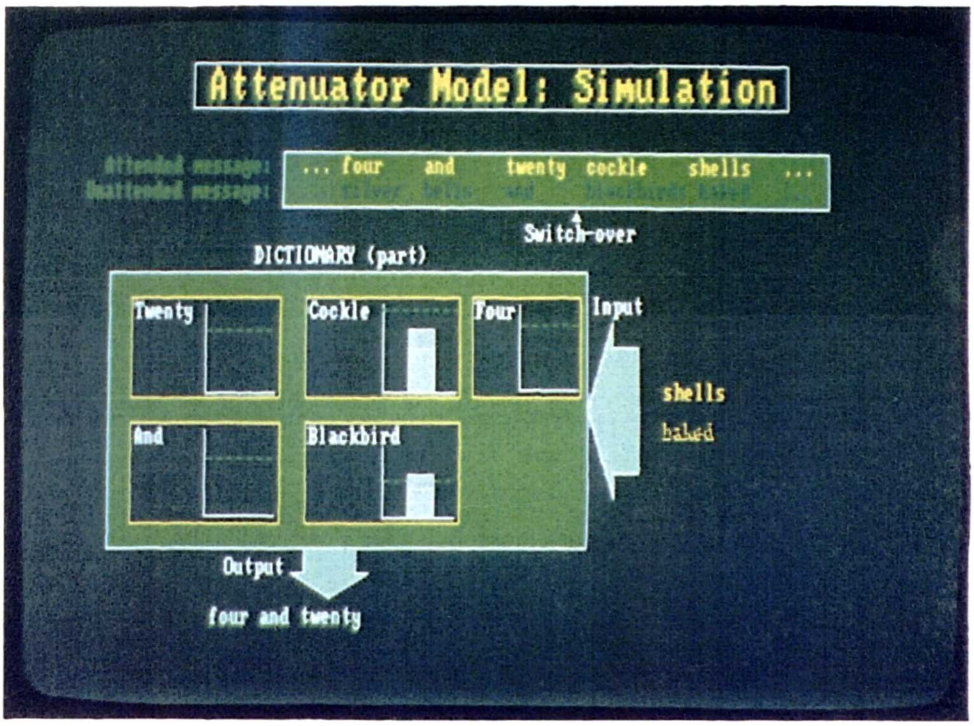


Figure 2.3(c)

2.5.4 Bottom-line-boxes

In addition to the main screen area containing the mouse selectable areas or links (either yellow-coded text or graphical elements), there is a single line at the bottom of the screen consisting of mouse-selectable generic facilities for access and guidance – namely, help, index, map, back-one, restart, further reading, quiz and end session. We will deal with these in two distinct groups, firstly we will briefly describe the utility functions of help, further reading and quiz. The next section will deal with those generic facilities that are assigned to navigation and system guidance. The quiz facility has a role within both groups.

Help

This is available from all screens and describes system usage and functionality of the various access mechanisms. Further description of the difficulty of designing appropriate help documentation can be found in Chapter 4. Figure 2.4 shows a typical help screen detailing functionality of the bottom-line boxes.

Further reading

Each information screen has an associated further reading screen, though each further reading screen may be associated with more than one information screen. The flexibility of the system allows these *further reading* screens to be linked to yet further *further reading* screens but this is generally not used for our current materials. Figure 2.5 shows a typical further reading screen.

Quiz

A quiz can be evoked from any information screen including the initial Welcome screen (shown in Figure 2.6). This quiz is context specific in that it will be on the topic currently being studied. For example if the current information screen was on iconic memory the quiz evoked would be the iconic memory quiz. The exception to this is for the Welcome screen. Evoking a quiz from this screen displays a menu of available quizzes. A typical quiz screen is shown in Figure 2.7 (a), and correct and incorrect choice responses shown in Figures 2.7 (b) and 2.7 (c) respectively. If the question is answered incorrectly, then the user is given the opportunity to attempt the question again or to embark on a tour to find further information (tours are discussed in Section 2.5.5). If the question is answered correctly, then the user is given the opportunity to try the next question. At all times, the user is able to leave the quiz and return to the information screen from which the quiz was invoked. As well as providing a self-testing facility, the quiz serves as a framework for knowledge assimilation, assists users in setting their own goals and navigational strategies. Quizzes can also be considered as an example of an *advance organiser*. Mayer & Bromage (1980) define such an organiser as a stimulus that "(a) is presented prior to learning and (b) contains a system for logically organizing the incoming information into a unified structure." Mayer & Bromage demonstrated that subjects who were exposed to an advance organiser prior to reading some technical text, performed better on the recall of conceptual ideas compared with subjects who were given the organiser after reading.

The following facilities relate to modes of navigation. The first two are concerned with major jumps in navigation – either to start again or to terminate the session. The third permits the user to retrace their steps – one screen at a time. Finally, the map and index facilities are discussed; these form a more structured means of navigation about the information base.

Re-start

On activation, the user is directly transferred to the Welcome screen. The back-one facility is no longer available (i.e., all previous activity cannot be retraced by the user) and all tours (either active or dormant) are cancelled.

End Session/Leave Quiz

On activating the 'End Session' bottom-line-box, the user is directly transferred to a screen asking them to confirm their intention or to return to the previous screen. The 'end-of-session' screen is, also, invoked if there has been no user activity for ten minutes, and if there is still no user activity for a further ten minute period the session is terminated. While the user is attempting a quiz, the 'End Session' box is replaced by a 'Leave Quiz' box. On activating this box, the user to transferred to the screen from which they invoked the quiz.

Back-one

On activating this bottom-line-box, the previously displayed screen is re-displayed. It is possible for the user to retrace their steps through a complete interaction session (i.e., backtracking). This facility is intended to help users to escape from *blind alleys* and to re-read earlier screens. The only limitation to this the list of visited screens is deleted whenever the first Welcome screen is encountered (i.e., the user invokes the re-start facility).

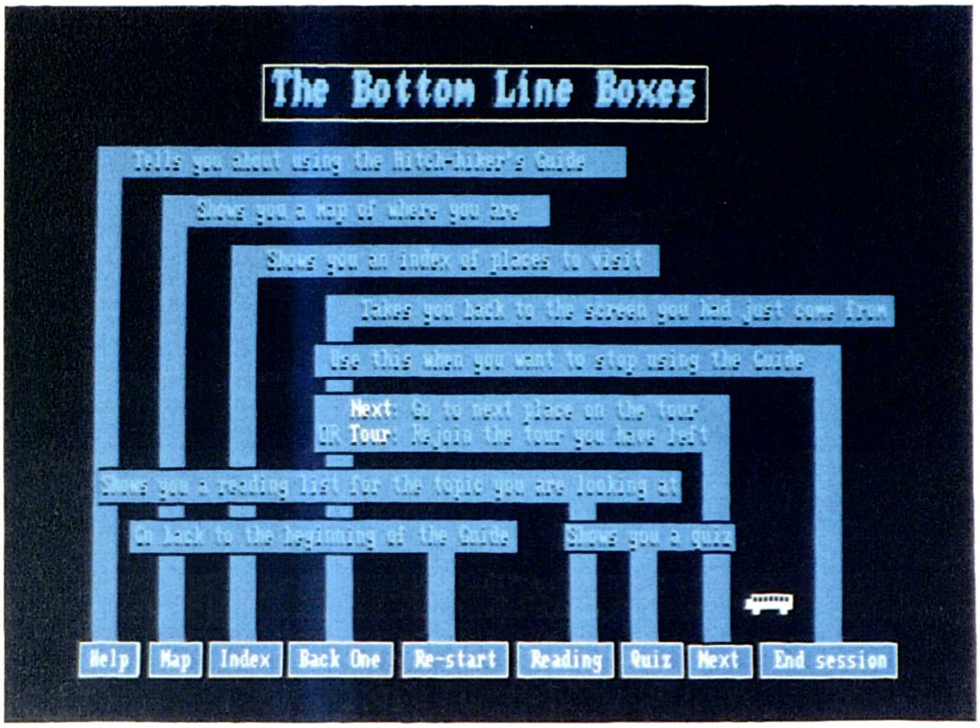


Figure 2.4 Example 'help' screen

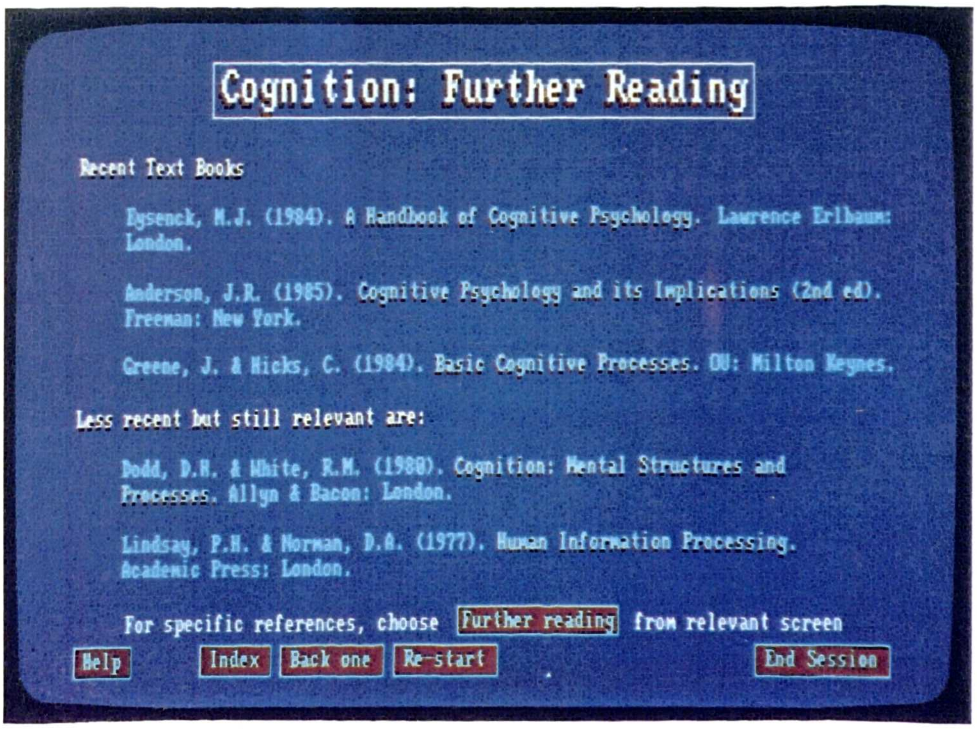


Figure 2.5 Example 'further reading' screen

Figure 2.6 Welcome screen

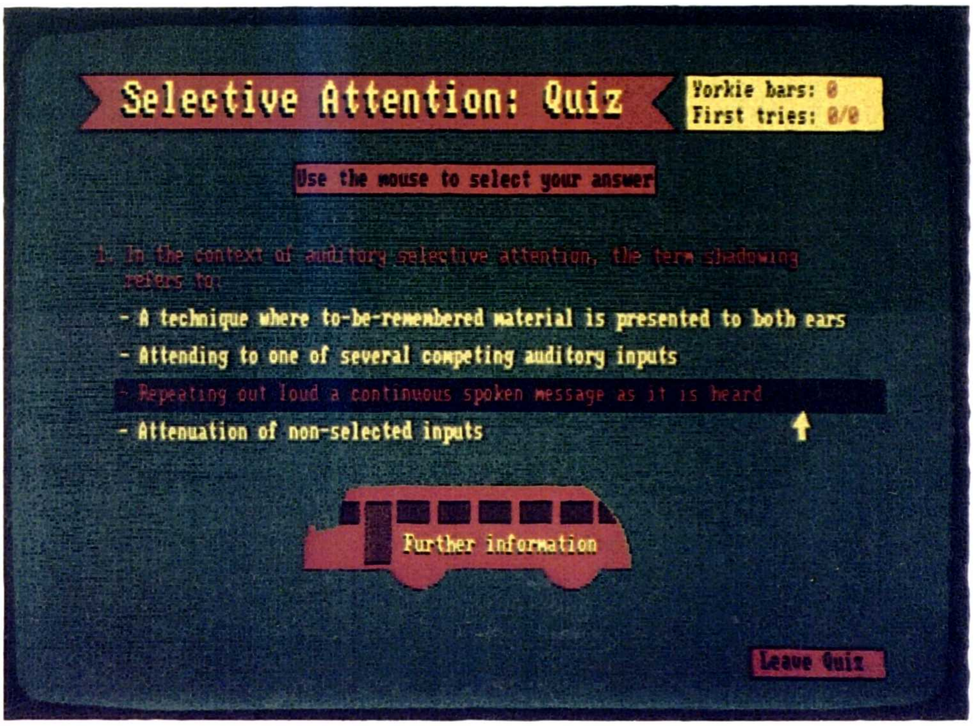


Figure 2.7 (a) Example quiz screen

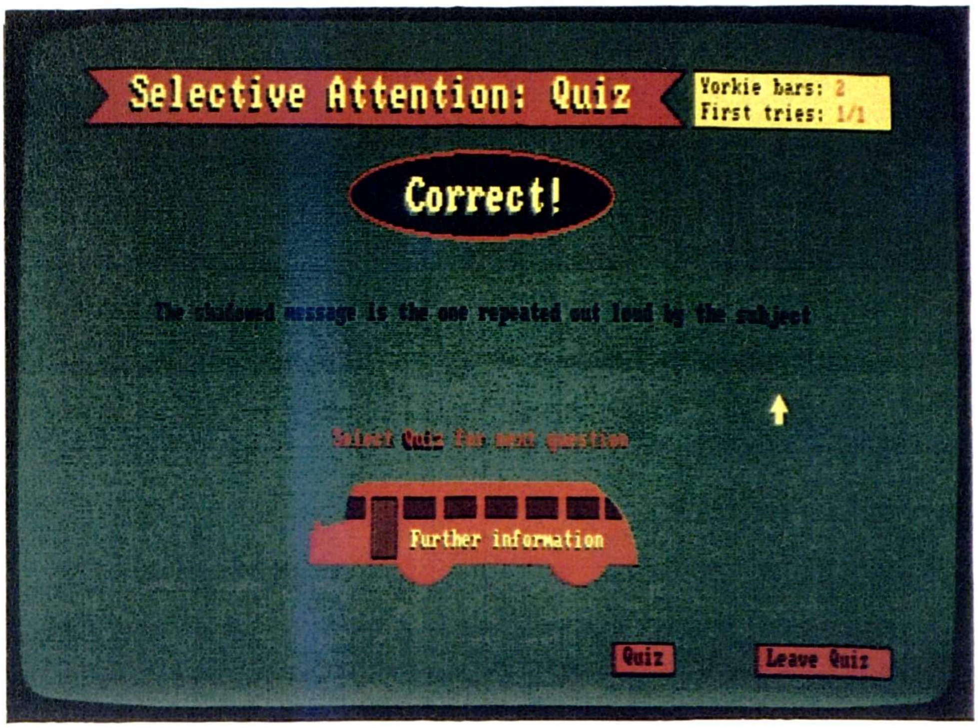


Figure 2.7 (b) Example of correct response to quiz screen

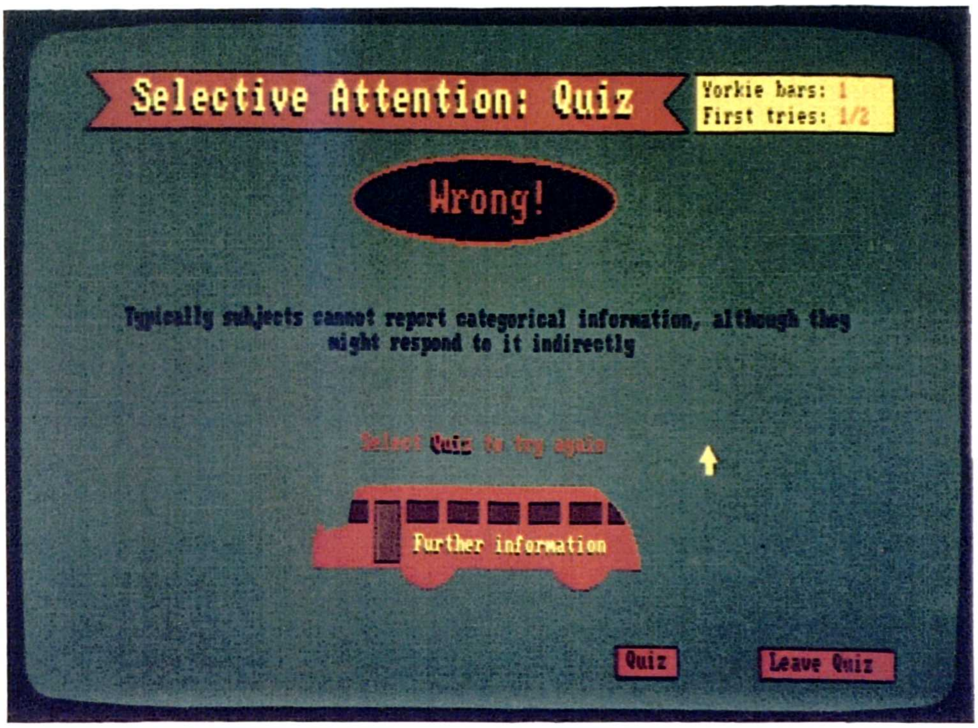


Figure 2.7 (c) Example of incorrect response to quiz screen

Index

This facility provides a list of key topics and words concerning the current information base module. On activating any entry, the user is transferred directly to the information screen concerning the selected entry. Screens within the current topic (e.g., iconic memory or focussed attention) are indicated by shadowed text – indicating which index entries are appropriate to the current topic area. As a further guide to users, index entries that initiated the start of a tour were marked by means of a suffix '[T]'. Figure 2.8 shows a typical index screen, with the two forms of identification mentioned clearly visible.

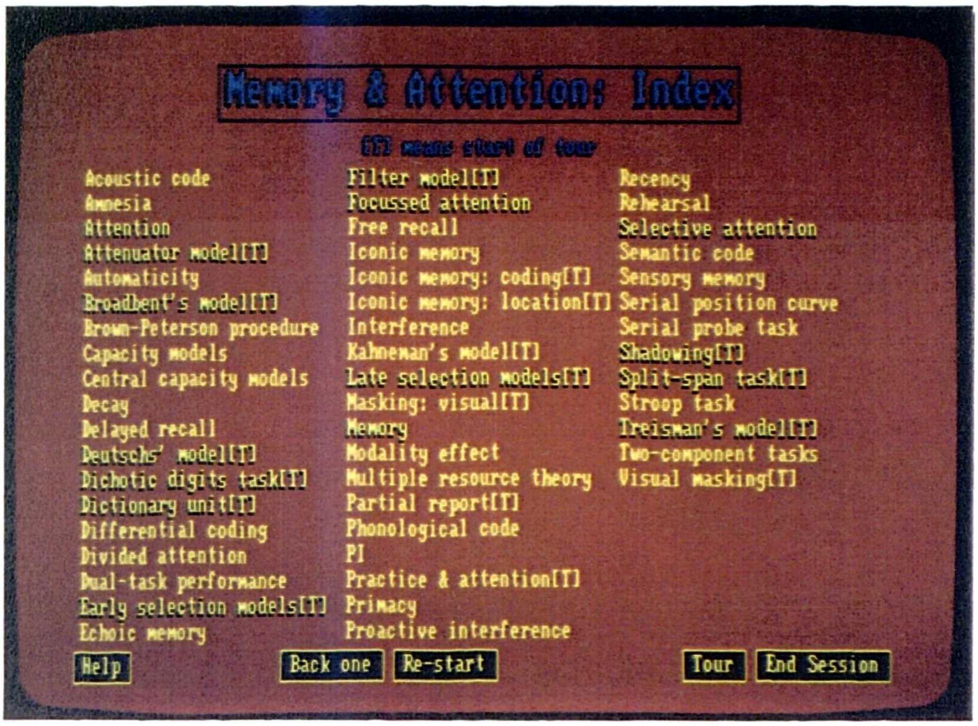


Figure 2.8 Example of index screen

Map

Just as with real maps, this facility allows a user to see where they are in the information base. Maps assist in knowledge integration since they provide an overview of the knowledge base through a structural representation of the materials. They also provide an important navigational tool – indicating which screens have been visted and those still left to visit. On selecting this bottom-line-box, the user is presented with a graphical representation of the appropriate portion of the current information network. Figures 2.9 (a-b) show two typical map screens. Due to the limitations of the graphical interface and, also, the wish to present an uncluttered representation of the information network, only a fraction of the network is shown on each map. Links, identified as 'MORE MAP', are provided to maps for other parts of the information network. It is always the one that shows the information screen from which the map facility was invoked. These map screens show by suitable highlighting the screen from which it was invoked and all other screens previously visited (colour coded white and dark blue respectively). This is an example of *footprinting*. Maps contain more information about the information base than do index screens; since they display graphically the structure of the network.

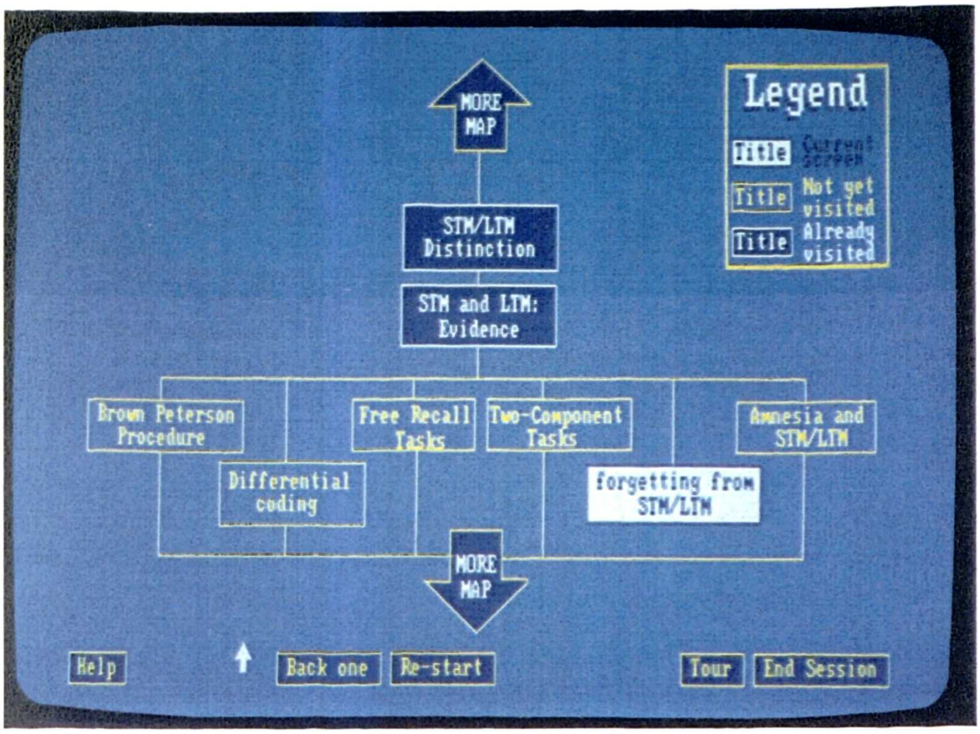


Figure 2.9(a) Example of map screen
Notice identification of current information screen and other screens previously visited.

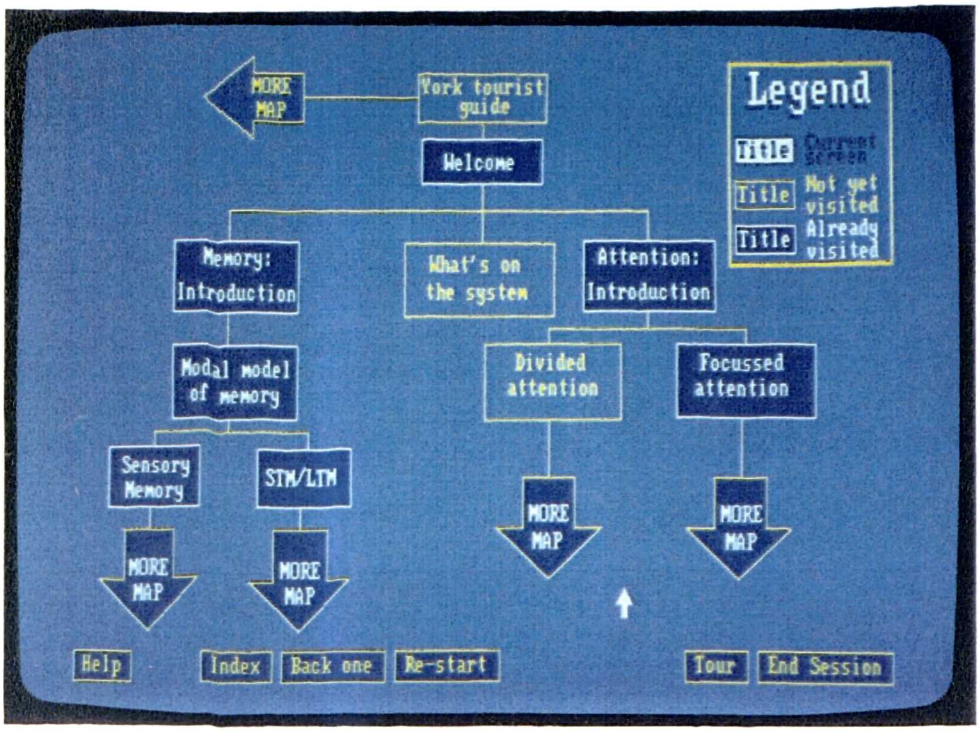


Figure 2.9 (b) Further example of map screen
This screen was called from the above screen, and so does not display the current information screen.

2.5.5 Guided tours

This navigational facility necessitates a section to itself as it is the main tutorial mechanism supported by the system and is more complex in operation. Tours start when users select an on-screen coach icon (labelled with the topic of the ensuing tour). Figures 2.10 and 2.11 illustrate information screens from which a tour or tours are available. The essential functionality of guided tours is shown in Figure 2.12. Further details are provided in Chapter 3. Once a tour is activated, the mouse icon is changed to a small coach shape (i.e.,) and the bottom-line-box labelled 'Next' appears. Figure 2.13 shows an information screen on 'Selective Attention and Shadowing' that is part of a guided tour. The user is guided around a prescribed sequence of information screens by selecting this box until the tour ends, at which point the user is returned to the starting point of the tour. The user can divert from the tour at any time by selecting a hypertext link or any other of the available bottom-line-boxes. The mouse icon reverts to the ↑ shape and the labelling of the 'Next' box changes to 'Tour' (as illustrated on Figures 2.8 and 2.9). The user may rejoin the tour, at the screen they left it from, by selecting this 'Tour' box.

Guided tours are able to provide a range in locus of control. While on a tour the user is under the safe control of the system, but they can leave at any time and so shift the control to themselves. There always remains the safety-net of rejoining the tour. It this way, the possible relationships between the learner, their goals and the learning materials are accommodated.

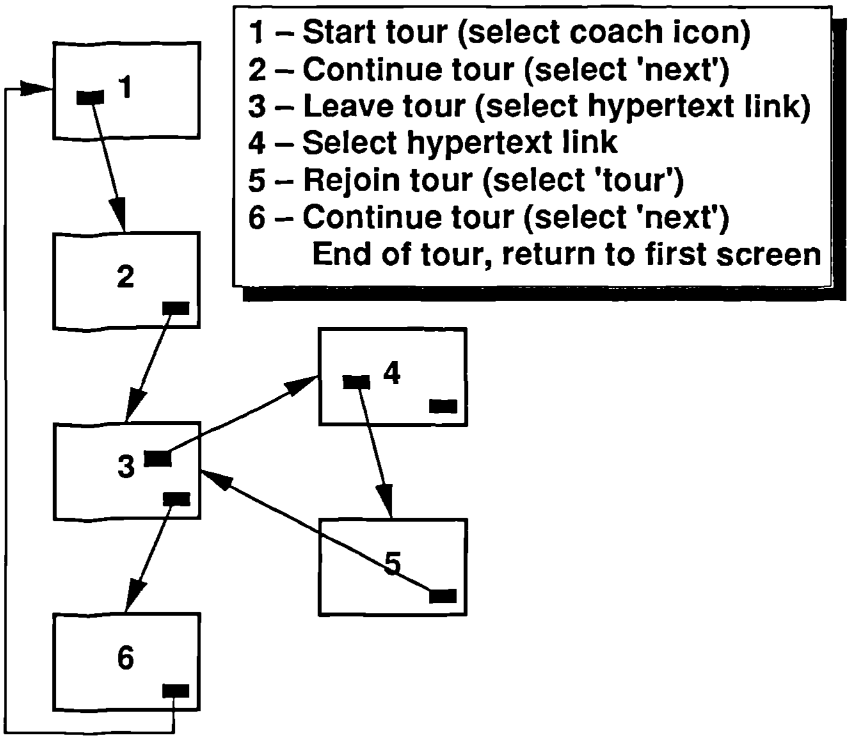


Figure 2.12 Basic navigation using the guided tour facility

2.5.6 Example of an interactive experiment

In order to further promote active learning a number of user-conducted experiments are included in the system. Such interactions assist learning in the following ways:–

- Permits users to engage with the learning material.
- Gives users experience of key psychological experiments.
- Provides users with distinctive retrieval cues, integrated into the learning material. This is not possible in conventional lecture presentations.

This section details one such experiment and hence gives an impression of the system's capabilities. The Stroop test (Stroop, 1935) demonstrates that subjects will become confused when presented with the task of identifying the presented colour of inappropriate "colour" words. For instance, reaction times and classification errors will be increased for the word "green" if displayed in yellow text compared with the word "green" displayed in green text. Figure 2.14 shows one of a number of choice screens. The choice made is logged, and the time between screen display and mouse activation is recorded as the user's reaction time. The results of this experiments are displayed as suitably scaled graphs of percentage correct classifications and averaged reaction times for the three categories of presentation (namely, matching, non-matching and control, e.g., words such as "horse"). A typical result screen is shown in Figure 2.15.

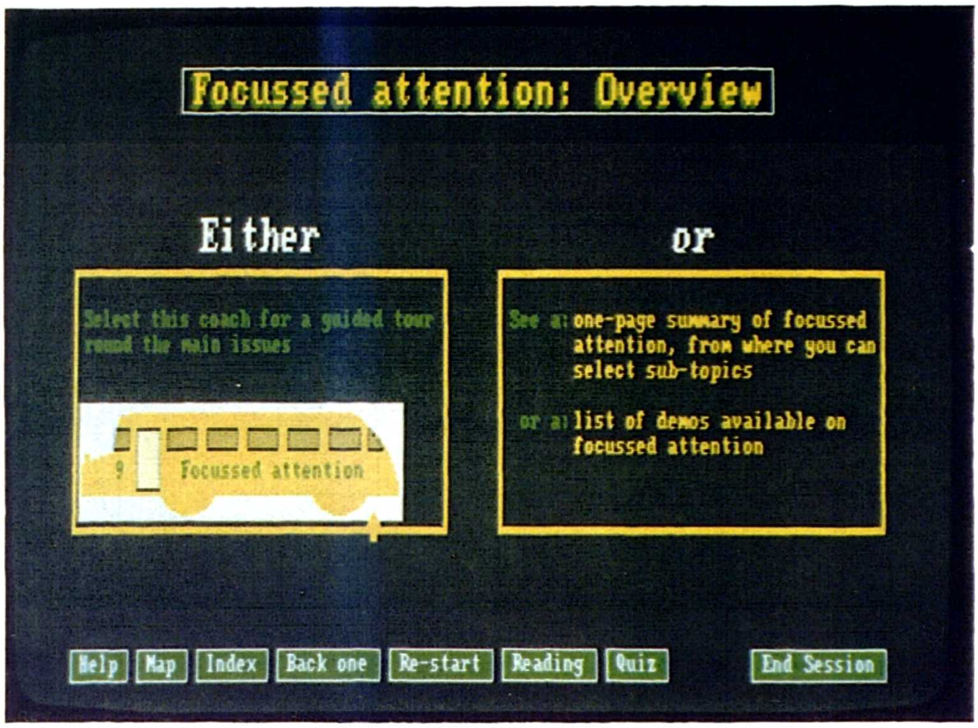


Figure 2.10 Example of an information screen containing the start of a guided tour

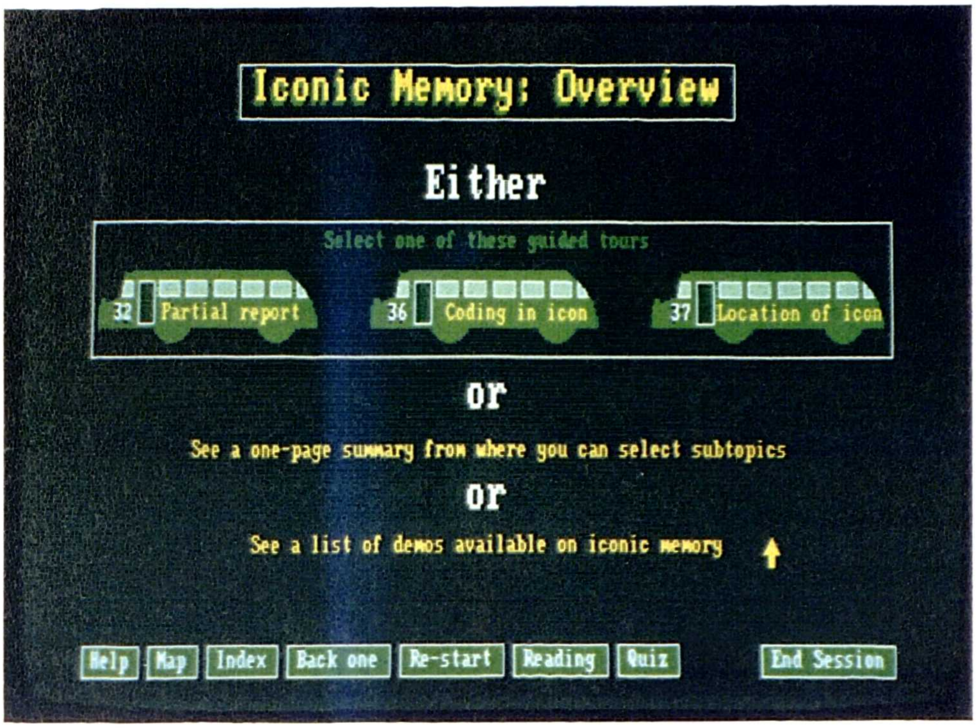


Figure 2.11 Example of an information screen containing the start of three guided tours

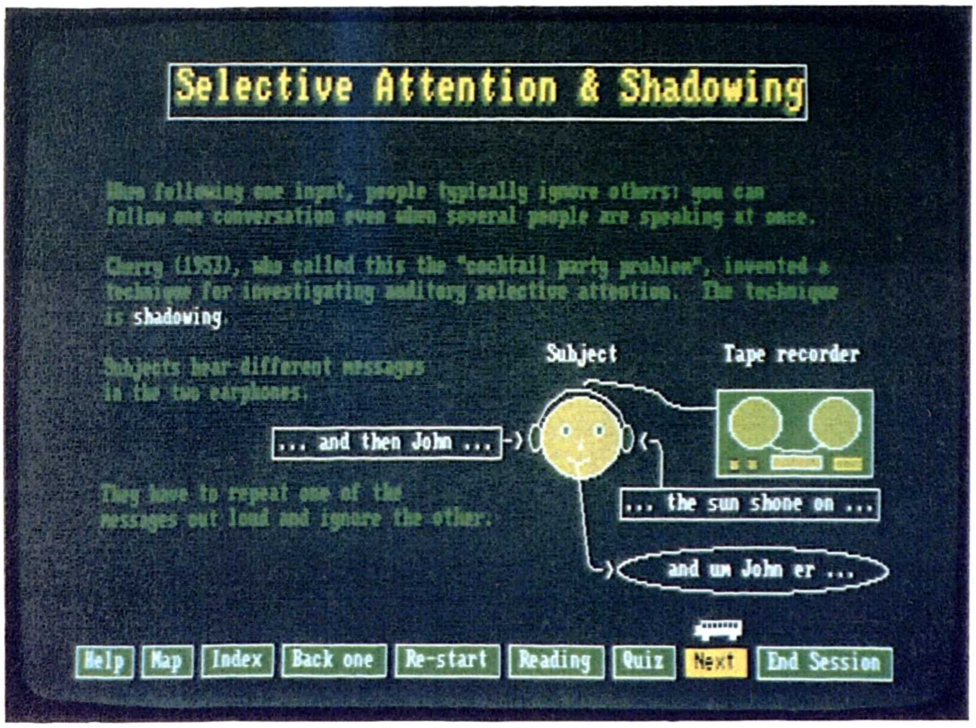


Figure 2.13 Example of an information screen as part of a guided tour

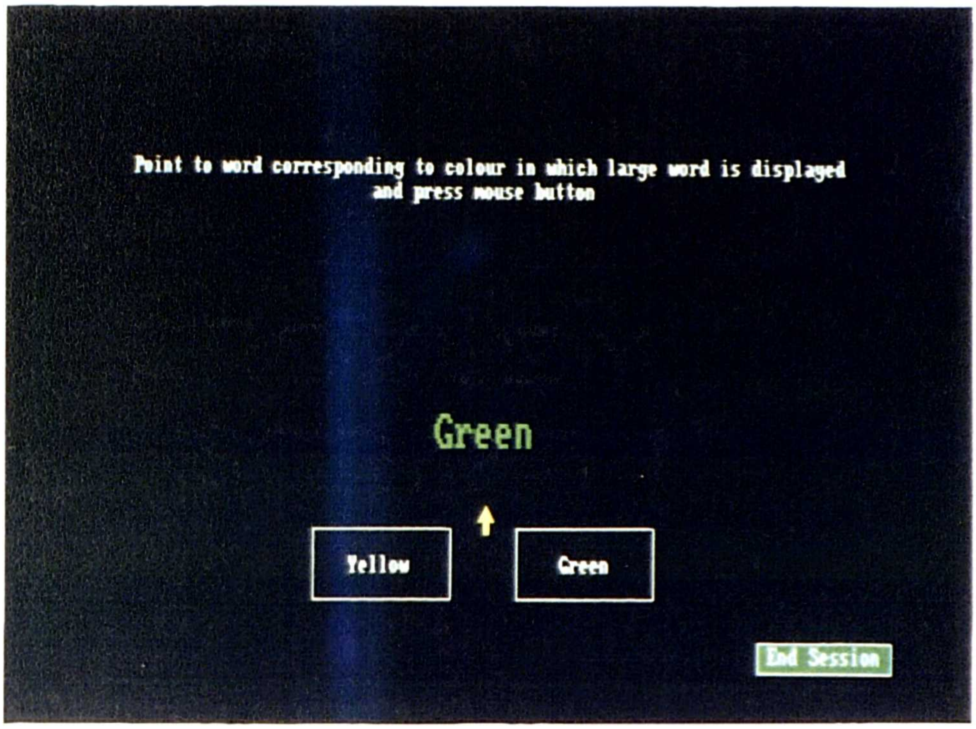


Figure 2.14 Example of choice screen for the Stroop test

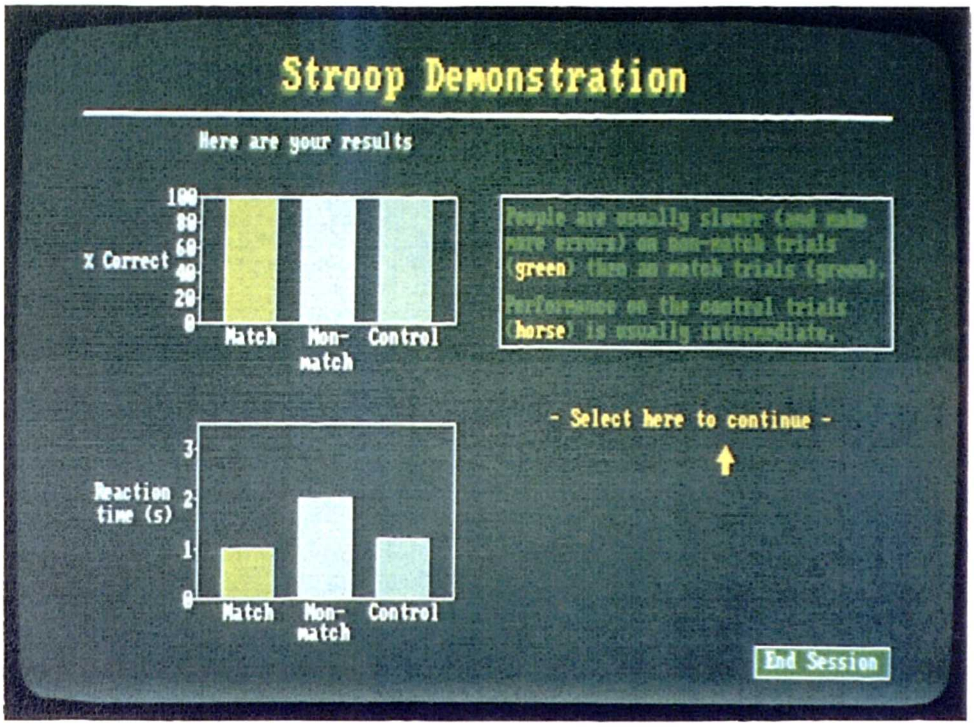


Figure 2.15 Results screen for the Stroop test

2.6 Discussion of Navigational Facilities

The purpose of this section is to discuss the various navigational facilities in terms of our choice of metaphor, namely the Travel Holiday. Though metaphors may be applied to a number of computing activities, it is those that may be termed the task-domain metaphor which are of interest to us here. Such a metaphor is intended to assist the user in understanding the tasks supported by the system. An example would be the terminology and icons used in the presentation of the Apple Macintosh filing system, for example this metaphor refers to a traditional paper filing system through the concept of *folders* rather than *directories* and *documents* rather than *files*. There are various divisions of task and system information, which have been discussed in terms of interface design (Jacob, 1983) and later applied to the use of metaphors by Hammond & Allinson (1987). These divisions are:–

- **Task information** concerns the structure and constraints that a system imposes on potential tasks.

- **Semantic information** concerns the facilities provided by the system and defines the set of entities in the task domain and the operations that can be performed on them.

- **Lexical information** refers to the terminology employed when discussing the system entities and operations.

- **Physical information** specifies the physical representation of the interface and the user actions.

A simple model of metaphor use is proposed in Hammond & Allinson (op cit.); this proposes that users process metaphors in two stages, namely:–

- **First stage – mapping abstraction** is where the user attempts to understand what kinds of information the metaphor conveys about the system. The user tries to map the entities in the metaphor (which is more familiar to them than those of the system) to those of the system. These mappings will not be consistent for every level of task and system information as introduced above. So the metaphor may (say) be accepted at the task level but rejected at the physical level.

- **Second stage – mapping invocation** is where the user attempts to call upon the metaphor in assisting them with a specific need. If the user lacks some knowledge for the performance of a task at the system level, then they will attempt to invoke the metaphor. However, if there is no adequate pre-formed mapping at this level then the metaphor will be ignored. Partial mappings can lead to users being misled.

The Travel Holiday metaphor is an attempt to allay the concerns of first-time users by making the functions of the various navigational facilities as transparent as possible. The metaphor maps the task, semantic and lexical levels of information but not the physical. There are two extremes forms of navigation *go-it-alone*, which we may term as *rambling*, and *guided tours*. These are at opposite ends of the user's locus of control dimension. For go-it-alone travel the user is free to move around the network by selecting the key items, identified by the yellow text (e.g., hypertext links). Typically, we would expect *go-it-alone* travel to involve the use of the map and index facilities as well.

Guided tours are the main tutorial mechanism supported by the system, and the system permits the user to divert from a tour at any time and re-join it later. These may be termed *excursions*. Such properties seem to fit well within our chosen metaphor. The map facility, which permits the learner to see where they are in the information network and so orienteer around this network, possesses *footprinting* properties not normally associated with real maps. The justification for extending the metaphor in this way is that conceptually these extensions appear easily understood and would, no doubt, be useful facility in real maps. The index could be considered as a simple form of guidebook, giving a list of places to visit. There are, of course, facilities (such as the multiple choice quizzes and further reading screens) that do not form part of the travel holiday metaphor. The users' recognition of the metaphor and the use of the various navigational facilities is discussed in Chapter 4.

The metaphor is identified to the users either implicitly through the design of the interface (e.g., the use of a coach icon to identify the start of a tour and the subsequent change of the mouse icon to a small coach) and even through the name of the system – the **Hitch-hiker's Guide**, and explicitly in the descriptions of the navigational facilities in the on-line help screens.

2.7 Preliminary Evaluations

During the early stages of the system development, evaluations were directed to many local aspects of system design rather than the success of the system as a whole. Small-scale evaluations were employed as part of the development philosophy, as recommended by Gould & Lewis (1985). With the presentation system, and to a lesser extent with the authoring tools, new facilities were tried out on potential users and note taken of their performance and comments. For the **Hitch-hiker's Guide** itself, the program during its growing development was used by pairs of students. These students were set specified tasks and were encouraged to think out aloud. The recorded dialogue was later collated with the log-files generated by the system. These log-files, the generation of which is discussed in Chapter 3, record accurately timed user interactions with the system. These evaluations proved to be important in identifying potential problem areas at an early stage in the system life-cycle. These problems and their remedies are discussed at the beginning of Chapter 4.

2.8 Summary

This Chapter has discussed, at the functional level, the properties of our LSE – the **Hitch-hiker's Guide** – and the design philosophy behind its development. The next Chapter presents in more detail the implementation of the **Guide** and the authoring tools created to support the generation of the information base and the integrated network of navigational facilities. Chapter 4 details the preliminary testing of not only the initial design stages but also the completed system in a *real* educational environment.

Before finishing this Chapter, one remaining design technique should be mentioned. Much of the success of the **Hitch-hiker's Guide** results from the close team-work between my supervisor and myself. Not only did we hold frequent meetings to discuss various aspects of design, but we put our thoughts into copious memos – that passed back and forth and initiated numerous "Reply to memo of ..." memos. Many points of design philosophy (and the difficulties of implementing some of them!) were thus argued through and, just as importantly, were preserved if not for posterity than as an essential aid in writing this thesis.

CHAPTER 3

IMPLEMENTATION OF "HITCH-HIKER'S GUIDE"

3.1 Introduction

Chapter 2 discussed the cognitive principles underlying the design of Hitch-Hiker's Guide and its functionality. This Chapter will describe in some depth the implementation of not only the presentation software aspects of the hypertext-based learning support environment but also the authoring software tools developed. The latter, it should be said, were not developed to as high a standard as the presentation software. This Chapter should not be viewed as the formal specification documentation for the programs developed, but as a description of the principles and extent of the programming work undertaken.

The layout of this Chapter is as follows. Brief details of the computer system and the software environment employed are presented, followed by a description of the structure of the external data structures used to hold screen information. The presentation program of the Hitch-Hiker's Guide, called **LINKER**, is then discussed in some depth. This discussion describes the implementation of the various navigational strategies introduced in Chapter 2. Other aspects of **LINKER** detailed include the provision of interactive graphics and screen routing, generation of log-files and the external directory handling techniques. Another requirement mentioned previously was that students should be unaware of the computer operating system, in order to minimise their need for computer literacy. This is the primary function of the parent program **SIGNIN**. Two secondary functions of this program are to provide system security and to identify users uniquely in order to generate appropriate logging data. Finally the authoring aspects of Hitch-Hiker's

Guide will be described. The major component is a screen editing program, called **PED**, but a small number of other utility programs were developed to provide further authoring facilities.

3.2 Introduction to Computing Platform

3.2.1 Research Machines Nimbus

The RM Nimbus is a small computer, similar to the **IBM** Personal Computer. It employs an **Intel** 80186 microprocessor operating at 12 MHz, and the workstations used for this work possessed an **IBM** keyboard, two-button mouse, 14-inch colour monitor and one Mbyte of RAM memory. The operating system is MS-DOS version 3.1.

3.2.2 Network details

Eight Nimbuses are connected via a local area network to a central file server. The file server was (for most of this project period) an Intel 80286 machine, with a 60 Mbyte hard disc and two Mbyte of RAM. A serial dot-matrix printer was also attached to the network, via the file server, which also acted as a print spooler.

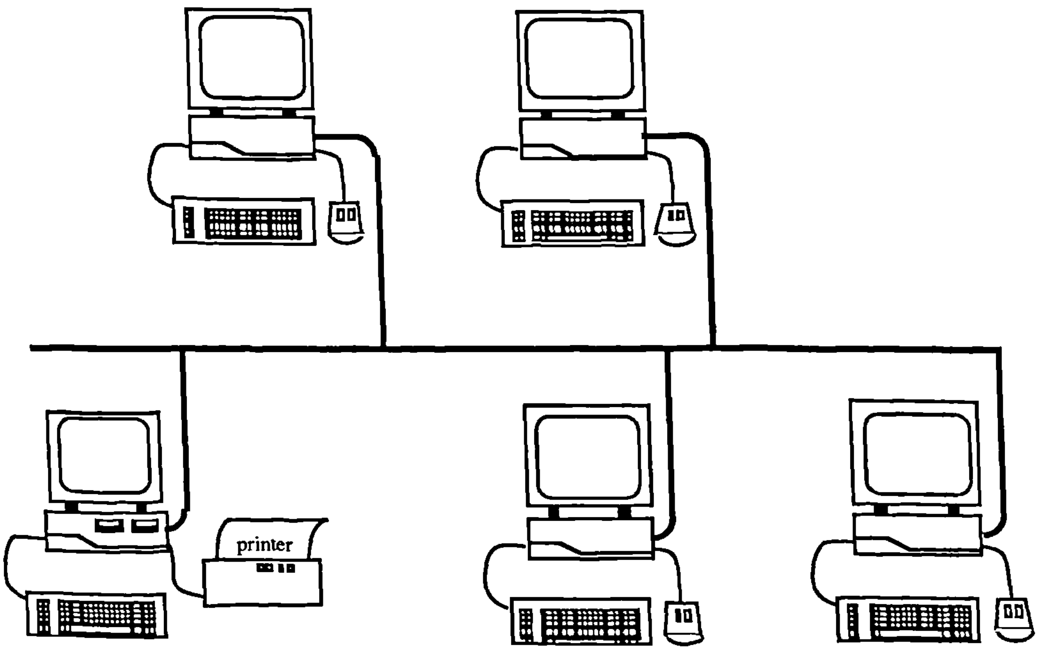


Figure 3.1 Computer network

3.2.3 Display screen details

The RM Nimbus display capabilities consist of a single physical, and logical, screen – in that there no facilities for rapid display switching and non-graphic text shares the same bit-mapped screen as the graphics. Many computer display systems employ different planes for the text and graphics, which though displayed as one screen, are treated as separate from a programming viewpoint. Two resolution modes are available – low (320 x 250 pixels) and high (640 x 250 pixels). All development has taken place using the high resolution mode. In this mode, four logical colours can be chosen from a palette of 16. The basic screen layout is shown in Figure 3.2. The screen border, around the active screen, can be any one of the 16 colours available. Extra colour effects can be created for solid regions of the screen by the use of dithering patterns. These are based on displaying various arrangements of the four logical colours over a 4 x 4 pixel array. Hence, an extra 16 "colours" are available. From the above description, it can be seen that the Nimbus display capabilities lie somewhere between the IBM CGA and EGA graphics standards.

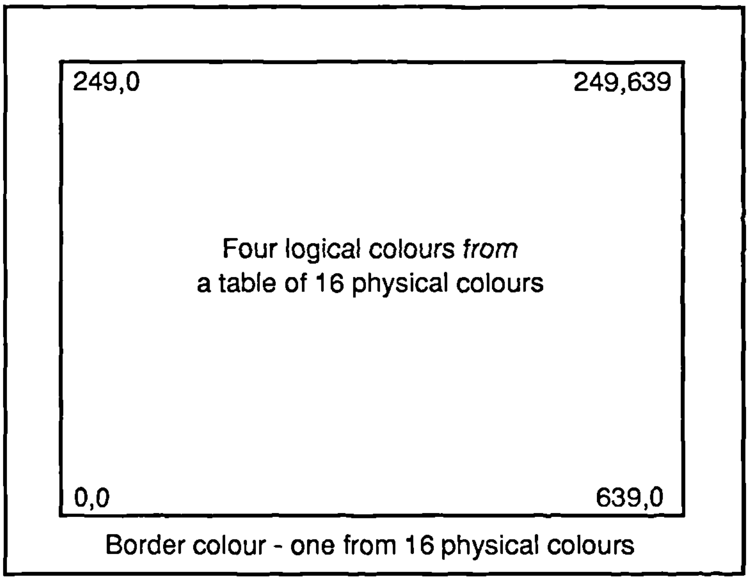


Figure 3.2 Screen format

3.2.4 Software environment

The operating system was MS-DOS version 3.1 or later, and the Pascal compiler used was Pro-Pascal version 2.1 (Prospero Software Ltd, London). This compiler is fully validated to the ISO Pascal level 0 standard, but contains a number of useful extensions. These extensions include dynamic strings for character and text manipulation, long integers, file handling, assembler-level interface and access to the computer's real-time clock. Other facilities are the ability to undertake separate compilation of program segments, use of *source include* files and the construction of procedure libraries. Due to the size of the many data structures employed, the extended address model was used for compilation to overcome the usual 64K byte program plus data limit of some compilers.

An early decision was that the graphics should be object-orientated, rather than employing a bit-mapped display (as in most computer painting packages). By referring to each graphical element as an object, its attributes (e.g., colour, size) can be modified at run time. Also non-graphical elements, such as active regions, sound and arithmetic functions, can be treated as objects within the same unified data structures. There are, of course, trade-offs between choosing an object-orientated approach as opposed to a bit-mapped approach in terms of memory requirements and display speed. The chosen platform for the implementation possessed custom electronic circuits for the fast generation of graphic objects. Comparisons of using these and using bit-mapped elements clearly demonstrated the speed advantages of the former. Another important factor is the ease of producing precise graphics compared with the traditional painting approach.

A graphics library was supplied by RM, that linked with the Pro-Pascal compiler. This library provided 89 procedures relating to graphics output and nine relating to graphics input (i.e., mouse and joystick handling). Many of these procedures are rudimentary, such as:-

```
Procedure SetcolourTableEntry(n,c:int);
Procedure SetBrush(b:brush);
Procedure FillCircle(x,y,r:int);
Procedure SetMouseLocation(x,y:int);
```

Only on one occasion was it found necessary to write assembly language routines, namely to change file directories from within the program. Also, it was necessary to develop a sound output library using the general interface routines to the RM Nimbus hardware.

3.3 External File Structures

3.3.1 Information screen files

The external files, which are created by the **P**icture **ED**itor (**PED**), hold the information for the drawing of the display screens by the presentation software. They also contain, as explained in Section 3.7.1, information for the control of the interactive features of presentation system. Details of these files are given below. Other external files, concerned with tour information and the recording of user activity (namely the individual user's logfiles) will be discussed later.

The external files for each information screen consist of two separate files, **SCREEN.$** and **TEXT.$**, where **$** is the screen number (1...999). The **SCREEN.$** is a binary file of variant records. It should be noted that the Pro-Pascal compiler, in common with most compilers, cannot create a true variant record file, but rather it produces a file with records of a fixed size corresponding to the size required by the largest record type. This limitation does result in some inefficiency of storage. For this reason, the text content of text records are held in a corresponding ASCII file **TEXT.$**. Details of these file structures are given in Figure 3.3. The textual contents for each graphical text element is terminated by the end of line marker. Hence, the maximum textual content of each element is 80 characters.

```
External name     -  SCREEN.$

Internal name     -  datafile

element       =  (line, box, circle, ellipse, arc, fill, text, active,
                      commons, delay, block, move, note, bitpic, arith,
                      graph, colour);

elerecord     =  record
                 case kind: element of
                 line:
                 box:
                 |
                 |
                 |
                 graph
                 colour
                 end{elerecord};

datafile      :  file of elerecord;

External name     -  TEXT.$

Internal name     -  textfile
```

Figure 3.3 File structures

3.3.2 Graphical primitives

The screen construction and display is based on an object-orientated approach, and not bit-mapped graphics. Such an approach permits the development of precise screen layouts, possibilities of animation and other dynamic effects and interfaces better with the supplied graphics library functions. The graphical primitives available are given Figure 3.4.

```
 colour -   select four logical colours from 16 available
            select screen border colour from 16 available

   line -   five styles (continuous, dotted, dashed, etc)
            five widths
            four logical colours

    box -   six outline styles (including no outline)
            five widths
            four outline colours
            13 centre colours (including eight patterns and transparent)

 circle -   five outline colours (including no outline)
            five widths
            13 centre colours (as for box)

ellipse -   as for circle

    arc -   as for line
   fill -   seed co-ordinates
            12 colours (including eight patterns)

   For all the above primitives, position and size can be specified

            Fill radiates outwards from the seed position until a
                   continuous boundary of a different logical colour is
                   reached

   text -   position (i.e., bottom left co-ordinates of first character
                   cell)
            content (string of up to 80 characters)
            four sizes (at 10, 20, 40 and 80 characters per screen
                   width)
            four colours
            four shadow modes (including none)
            four directions (at 0°, 90°, 180° and 270° to horizontal)
            two character fonts

 bitpic -   file extension of bit-mapped graphics file
            position (i.e., bottom left co-ordinates)
```

Figure 3.4 Graphical primitives available

3.3.3 Animation primitives

The animation primitives are available as specified in Figure 3.5.

delay	-	duration (resolution in $\frac{1}{10}$ seconds) action (i.e., add to or clear current screen display)
block	-	co-ordinates of rectangular area for subsequent animation
move	-	x and y increments for each move number of steps time delay per step (resolution in $\frac{1}{10}$ seconds) action (i.e., copy or move)

Figure 3.5 Animation primitives available

3.3.4 Bit-mapped picture primitive

The facility to introduce bit-mapped pictures into the presentation software, which have been produced by grabbing a single television frame from a video camera, was developed. These pictures were acquired using a **Pluto** graphics system controlled by an IBM-AT computer. A utility program was developed that converted these files from the Pluto format to a format suitable for the RM Nimbus screen. The Pluto system was capable of displaying a full 24-bit colour image, while the Nimbus is limited to four logical colours per screen in the high resolution mode. The image files from the Pluto system could only be limited to a minimum of 64 colours. Hence, it is necessary to map this larger number of colours onto the four permitted. An intensity histogram equalisation was normally used as it usually produced the best visual effect. This means that the four permitted colours in the Nimbus picture format contain as far as possible equal numbers of pixels of each colour. This mapping is illustrated in Figure 3.6.

The format of the Nimbus picture files is an eight word header followed by a data area of the following size:–

$$(y_{max} - y_{min} + 1) * \text{round}\left(1 + \frac{x_{max} - x_{min} + 1}{\text{pixels per word}}\right) \quad \text{words}$$

In the high resolution mode used, there are eight pixels per word. The header contains such information as the height and width of the picture block in pixels.

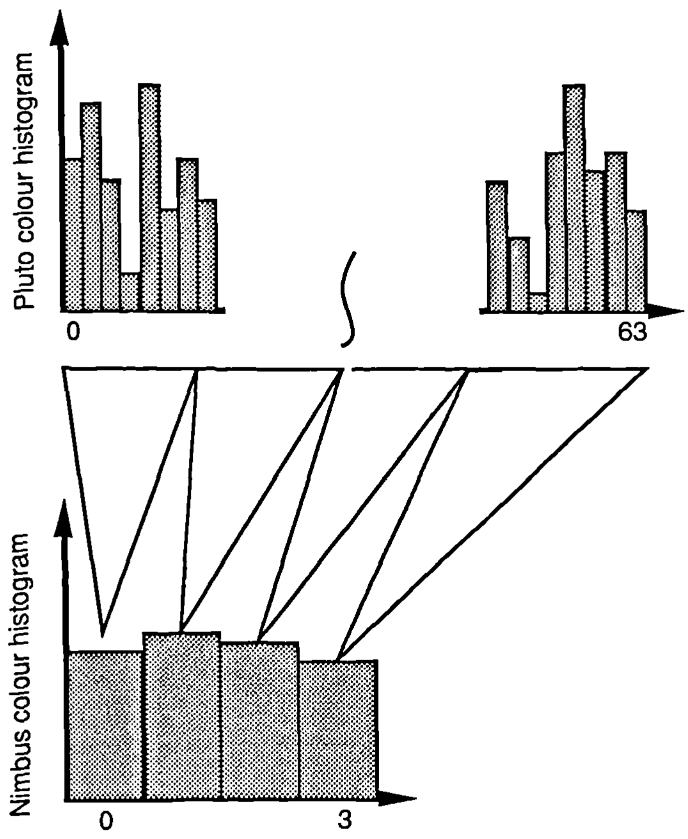


Figure 3.6 Histogram equalisation of bit-mapped pictures

The utility program, also, possessed facilities for cropping the picture to the desired size and rudimentary touch-up facilities, such as a single-pixel pencil. The graphics element in the **SCREEN.$** file consists of:–

```
bitpicdata =     record
                 picext:integer {file extension};
                 xlow, ylow:int{lower left corner co-ordinates}
                 end{bitpicdata};
```

The data for the bit-mapped images are held in a separate binary file, called **BITPIC.$**. No attempt is made to employ any form of data compression on these files, as experiments demonstrated that various forms of compression only extended the time before the picture was displayed. Even so the file reading and screen display could take up to 30 seconds for a large picture. Hence, it was usual to display a message stating something such as "Watch this space..." in the area where a picture would appear. This message, of course, would be become invisible once the picture was drawn. The **BITPIC.$** file is read into non-graphics memory, and when this process is complete, this block of memory is transferred to the screen memory. Hence, the picture is displayed in its entirety after the file reading delay, rather than being displayed line by line on the screen.

3.3.5 Sound primitive

The RM Nimbus possesses an Intel 8910 synthesizer chip which has three sound channels allowing three different sounds to be played at the same time. Each channel can produce either pink noise[1] , or a pure note, or a combination of the two. The sound envelope, that is the volume-time curve, can be specified. The sound record contains an array of 13 elements, of the form:–

```
notetype = array[1...13] of int;
```

The meaning of each of these elements, with reference to the sketch of the user-defined envelope shape (Figure 3.7), is given in Figure 3.8. All timings are in milliseconds. Pitch may be set from 0 to 388, where 148 is middle C and 196 is the C one octave above this.

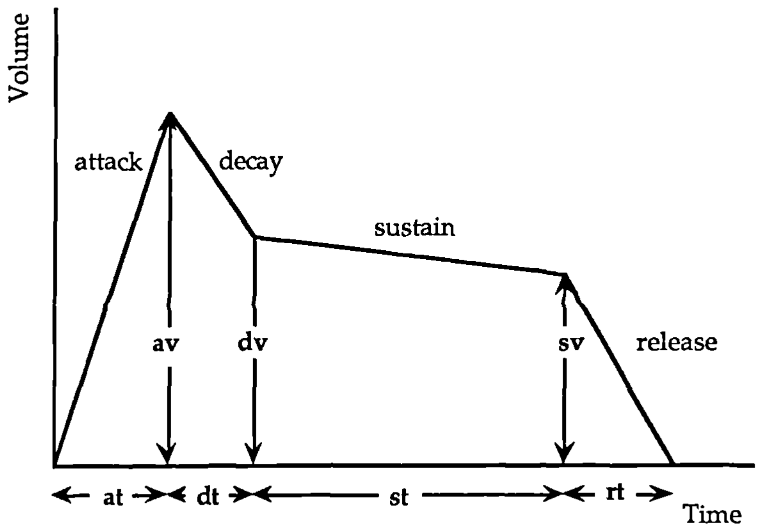


Figure 3.7 Sound Intensity Envelope

[1] The power spectrum of pink noise falls at 6 dB/octave.

```
notearray[1]      = channel number (1, 2, 3);
notearray[2]      = attack time (at);
notearray[3]      = volume at end of attack (av);
notearray[4]      = decay time (dt);
notearray[5]      = volume at end of decay (dv);
notearray[6]      = sustain time (st);
notearray[7]      = volume at end of sustain (sv);
notearray[8]      = release time (rt);
notearray[9]      = noise enable;
notearray[10]     = tone enable;
notearray[11]     = synchronization flag;
notearray[12]     = start pitch;
notearray[13]     = end pitch;
```

Figure 3.8 Definition of 'sound' record

3.4 Presentation Program

3.4.1 Overview

LINKER is the presentation component of the hypertext system. It is the only executable file required in order to run the system with previously generated information screen files. The user interface is entirely through mouse positioning and mouse button activation. The following program description is not intended to be a full technical documentation of the program, but rather it outlines the overall functionality of the program and highlights various implementation details. With reference to Figure 3.9, at the highest level the program consists of the three sequential modules detailed in Figure 3.10.

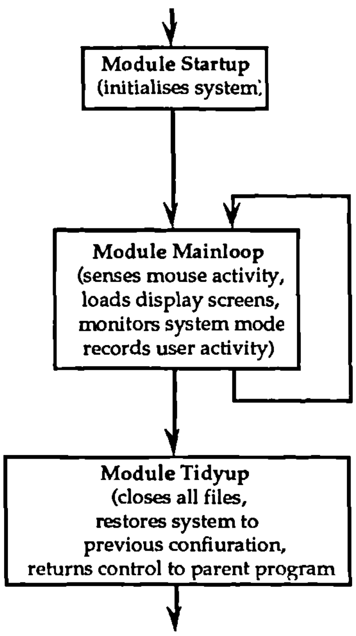


Figure 3.9 Overall Functionality of **LINKER**

```
Module  startup
Initialises all graphical input and output procedures;
Saves current graphical parameters (e.g., resolution, colour table);
Removes cursor and re-directs all text input (files or keyboard entry)
       to invisible files;
Resets all internal variables and data structures (i.e., all dynamic
       structures are set to nil);
Loads sprite files and dynamically reserves memory for these and other
       graphical blocks;
Loads first information screen (i.e., ScreenNumber = 1); if not present
       terminates program and returns error code to parent program;
Writes start to logfile and date and time-stamp;
Set initial mouse position and display mouse sprite;

Module  mainloop
Stop set to false;
While not stop do
  begin
    Enquire current position of mouse (x,y);
    If (new mouse position) or (new screen loaded) then
      begin
        Move sprite to new position (x,y);
        If position (x,y) is within any active area of screen then
          begin
            If current active area not highlighted then
              begin
                Highlight active area;
                CurrentCode set to current active area code number;
                Set found to true
              end
            end;
        Set old position (x',y') to current position (x,y);
      end;
    Enquire status of mouse buttons (left,right);
    Set status of watch-dog facility (left,right,stop);
    {Watch-dog monitors non-activity of user - see Chapter 2}
    Mouse dialogue (CurrentCode, left, right,found, stop)
  end

Module  tidyup
Writes finish to logfile and time-stamp;
Clears screen;
Restores previous graphics parameters (i.e., resolution and colour table);
Switch off mouse input and sound output;
Restores cursor;
Returns error code to parent program;
```

Figure 3.10 Code overview of **LINKER**

3.4.2 LINKER data structures

This section will describe only the main data structures employed in **LINKER**. A substantial use is made of dynamic data structures. A number of dynamic singly-linked lists, implemented either as stacks or queues, were employed. A brief description of the main data structures is given below:–

a. Graphical screen elements

List of all graphical elements used to generate the current screen

```
eleptr =      ^eletype;
eletype =     record
              {Common part}
              next : eleptr;
              case kind : element of
              line : (linebits : linedata);
              box : (boxbits : boxdata);
              circle : (circlebits : circledata);
              ellipse : (ellipsebits : ellipsedata);
              arc : (arcbits : arcdata);
              fill : (fillbits : filldata);
              bitpic : (bitpicbits : bitpicdata);
              graph : (graphbits : graphdata);
              texts : (textbits : textdata);
              delay : (delaybits : delaydata);
              block : (blockbits : blockdata);
              move : (movebits : movedata);
              note : (notebits : notedata);
              active : (activebits : activedata);
              arith : (arithbits : arithdata)
              end(eletype);
```

The graphical element queue is referenced through:–

```
var
ElementHead,ElementTail : eleptr;
```

The arithmetic elements are stored in a separate queue as they are called at a different point to the screen drawing and are referenced through:–

```
var
ArithHead,ArithTail : eleptr;
```

The active areas are stored in a separate stack as they are called after the mouse has been activated, and a separate stack reduces the search time. They are referenced through:–

```
var
ActiveHead : eleptr;
```

b. Bottom-line-boxes Active Areas

List of the common active areas at bottom of each screen

```
comptr =     ^comtype;
comtype =    record
             next : comptr;
             effect : integer;
             activebits : activedata
             end{comtype};
```

The common active areas are referenced through:–

```
var

CommHead, CommTail : comptr;
```

c. Screen code number lists

Lists of screen code numbers for back-one and guided tours facilities

```
link =          ^scandata;
scandata =      record
                next : link;
                data : integer
                end{scandata};
```

The stack of screens previously visited, used for back-one facility and the generation of footprinting on map screens, is referenced through:–

```
var

TopLink : link;
```

The queue for the information screens in the current guided tour, generated from an external file, is referenced through:–

```
var

TourTop,TourLast : link;
```

There are a number of global variables which monitor and control the current status, and past history, of the program. For example:–

```
var
effect : integer{mode status of system based on common active area selection};
           LastEffect  : integer{previous mode status};
     CurrentScreenCode : integer{current screen code number};
    PreviousScreenCode : integer{previous screen code number};
       EnterTourScreen : integer{last screen before entering guided tour};
       EnterQuizScreen : integer{last screen before entering quiz};
        LeftQuizScreen : integer{last screen before leaving quiz};
```

These variables, together with others, will be introduced in the following sections.

3.4.3 Sprite handling

The mouse pointers are implemented using the software generated sprite facility provided in the RM Nimbus sub-BIOS firmware. A sprite is a collective group of pixels that can move swiftly about a graphics screen without affecting the background picture on the screen. The data structures for sprites are quite complicated, and the two sprites used (namely a basic arrow for all modes except guided tours, and a coach icon used for guided tours) were generated using a sprite editor supplied by RM. These sprites are held in two external binary files (**SPRITE1.BIN** and **SPRITE2.BIN**), and are loaded during program initialisation. Internally, the sprites are held in a contiguous block of RAM. The graphics library provides external procedure calls to define sprites, assign memory, draw and move sprites. (The erase sprite procedure call did not function). Each sprite possesses a hot-spot which should be regarded as the centre of the sprite and is defined when the sprite is created. The screen co-ordinates of this hot-spot should correspond to the current mouse location. However, there is an error in the sprite editor which requires the use of x and y offsets in the screen co-ordinates to ensure correct positioning of the sprite on screen.

The movement and display of the appropriate sprite (determined by the state of the variable spritetype) is performed within the mainloop module. The basic method is illustrated in the program segment shown in Figure 3.12.

```
begin
  EnqLocation(mouse,x,y);
  If (x <> oldx) or (y <> oldy) then
    begin
      case spritetype of
      {move sprite to off-screen location as EraseSprite call does not work}
        1: MoveSprite(oldx + 2, oldy - 6, -1023, -1023);
        2: MoveSprite(oldx + 6, oldy + 1, -1023, -1023)
      end{case};
      case spritetype of
      {re-draw correct sprite - note hot-spot fudge factors}
        1: DrawSprite(x + 2, y - 6);
        2: DrawSprite (x + 6, y + 1)
      end{case};
      oldx:=x; oldy:=y
    end{If (x <> oldx)....};
```

Figure 3.12 Sprite handling code segment

3.4.4 Mouse dialogue

As the graphics interface library **Procedure** `MouseSwitches (`*`left,right`*` :boolean)` simply returns the current instantaneous status of the mouse buttons, the pressing of a button cannot be employed to activate further procedures as multiple events would be detected. This would lead to unpredictable performance of the system. The status of the buttons needs to be latched so it is the release of the buttons which initiates user actions. The implementation of this latching function is clear from the following pseudo-code description of the mouse dialogue. The mouse dialogue is further complicated as it needs to perform the follows two functions:–

- If only one button is pressed and released over a previously highlighted active area, then this area is activated. It is possible to abort this activation either by moving the mouse out of the active area before releasing the button, or by pressing both buttons.

- If both buttons are pressed then all active areas in the current screen are highlighted. They are dimmed again by releasing the mouse buttons.

The full functionality of the mouse dialogue is shown in Table 3.1. The detailed mouse dialogue procedure is given in Figure 3.13.

Table 3.1 Mouse dialogue

	Context	User action	System response
1	Out of active areas	Move mouse, and/or press buttons	No response
2	Within an active area	Move mouse and no buttons pressed	Highlight active area under pointer
3	Within an active area	Press a single button	Prime system, but take no action
4	Within an active area	Release button	Take action (e.g., load next screen)
5	Out of active areas	Release button	No response
6	Anywhere	Press both buttons	Highlight all active areas
7	Anywhere	Release both buttons	Remove all highlighting, except the current active area (if any) but take no action

Notice the writing to the logfile of all button activity and its time stamping. This recording, especially of the single button presses, enables the recording of the exact period a user has viewed a screen before making a decision. It also permits the screen loading time to be calculated, in order to monitor program performance on the computer network.

3.4.5 Screen and mode control

Two control variables initiate the loading and display of screens and modifying the mode status of the system, namely:-

- `CurrentCode` - integer variable derived from the currently activated active area. The range and meaning of this variables are as follows:-

1...999	- screen number, i.e., file extension of external **SCREEN.$** and **TEXT.$** files. There are the following special/reserved screen numbers:-
1	- initial start-up screen
401	- exit screen
999	- used as dummy exit code to set global flag done to true
850...899	- map screen
remainder	- normal information screen
1001...1999	- equates to tour number, where tour number,$ = (CurrentCode - 1000). $ is used as the file extension to the external tour file **TOUR.$**.

```
Procedure dialogue ( CurrentCode:integer {screen code number};
                     left, right:boolean {mouse button status};
                     found:boolean {mouse position over an active area};
                     stop:boolean {program primed to be terminated});
begin
If not (left or right) then
{no buttons currently pressed}
  begin
    If both then
    {both buttons pressed previously and flag both set}
      begin
        set both to false;
        dim all active areas;
        write 'D' to logfile and time stamp
      end;
    If found and either then
    {active area has been located at current mouse position, highlighted and
       flag found set, one of the mouse buttons pressed and flag either set}
      begin
        set either to false;
        write 'B' to logfile and time stamp;
        TakeAction(CurrentCode,effect,stop)
      end;
    If not found and either then
    {no active area at current mouse position, and only one of the mouse
       buttons pressed and flag either set}
      set either to false {cancel previous mouse action};
  end{If not (left or right)...};

If (not left and right) or (left and not right) then
{only one mouse button pressed - i.e., exclusive-or function}
  begin
    If found and not either then
    {an active area has been located at current mouse position, highlighted
       and flag found set, but either not set}
      set either to true {prime system};
  end{If (not left and right)...};

If (left and right) then
{both mouse buttons pressed}
  begin
    If not both then
      begin
        set both to true;
        highlight all active areas;
        write 'A' to logfile and time stamp;
        If either then
        {cancel single button press}
          begin
            set either to false;
            set found to false
          end
      end {If not both...}
    end {If (left or right)...}
end{dialogue};
```

Figure 3.13 Mouse dialogue procedure

- `EffectCode` - integer variable derived from type of currently activated area (i.e., hypertext link or bottom-line-box). The meaning of this variable is as follows:-

  0 - next screen
  1 - help
  2 - back one
  3 - restart
  4 - index
  5 - reading
  6 - exit
  7 - map
  8 - quiz
  9 - tour

The procedure of Figure 3.14 initiates screen changes, dependent on the current activated active area, and current and previous modes of the system.

```
Procedure TakeAction(var CurrentCode, effect:integer;
                                    var done:boolean);

If (CurrentCode > 1000) and (effect = 0) then
{start new tour}
  begin
    Start tour;
    If success then
      get tour screen
  end
else
  begin
    If (CurrentCode = 999) and (effect = 0) then
    {set done to exit program}
      set done to true
    else
       begin
        If CurrentCode in [850...899] then
        {map screen activated}
          get map screen
        else
        {test for all other effects}
          begin
            case effect of
              0,4,5  : get new screen;
              1      : activate help mode and get first help screen;
              2      : get previous screen;
              3      : activate restart;
              6      : get exit screen;
              8      : activate quiz mode and get first quiz screen;
              9      : get next tour screen
            end{case effect...}
          end{If (CurrentCode in [850...}
        end{If CurrentCode = 999...}
     end{If CurrentCode > 1000...}
end{TakeAction};
```

Figure 3.14 Procedure for controlling screen changes

3.5 Navigational Modes

3.5.1 Protocols

All navigation is based on the user selecting one of a number of active areas. Each active area, for the current screen, is maintained in a queue that is searched to obtain the details of the currently selected area. Each active area record is composed of the following fields:–

```
activedata =     record
                 xlow,ylow:int{lower left corner co-ordinates};
                 xup,yup:int{upper right corner co-ordinates};
                 lit:boolean{if highlighted, set to true};
                 active:boolean{if currently activated, set to true};
                 codenum:integer{destination code - screen or tour number}
                 end{activedata};
```

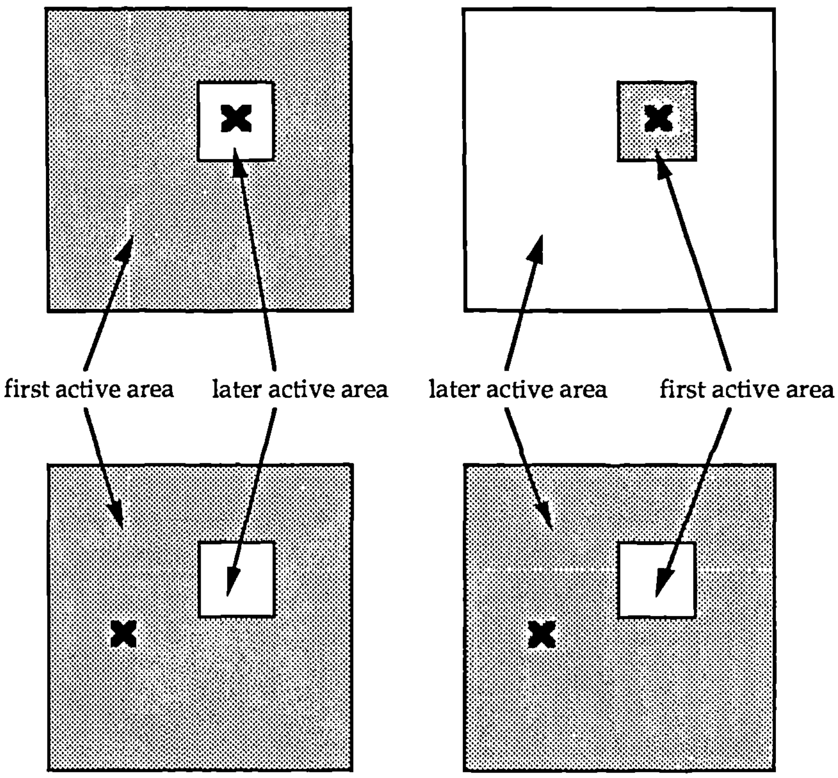


Figure 3.15 Activation of nested active areas

The common active areas, or bottom line boxes, have an additional field, namely `effect:integer`, which is employed to monitor the current mode of **LINKER**. The common areas are searched first for a currently activated area, and then the remainder of the screen's active areas. Only one area can be active at any one time, and hence overlapping, or nested, active areas can pose a conflict. It is the first encountered active area in the active area queue that is activated. This effect is illustrated in Figure 3.15. Hence, the inner-most active area should appear first in this queue.

The modes corresponding to `effects` {0, 4, 5} (namely, hyperlink, index and reading) will be discussed first as they represent the simplest form of screen linkages.

3.5.2 Hyperlink, index and reading protocols

Hyperlink is a conventional hypertext link. The basic algorithm is given in Figure 3.16. If the new screen files are not found, then the following message is displayed for 2.5 seconds, before redrawing the previous screen:–

Screen not available in this module

```
Procedure GetNewScreen(      ScreenCode,effect:integer;
                                  var success:boolean);

begin
  Test variable array element, varray[1], for route changing
    {see later section};
  Check if next screen is same as end of last tour or next on tour
    {see later section};

  If files SCREEN.ScreenCode and TEXT.ScreenCode exist then
     begin
      Set success to true;
      Assign files to internal files;
      Note last effect;
      Push ScreenCode on previous stack;
      Write to logfile effect, ScreenCode, and time stamp;
      Create map list (ScreenCode);
      Draw new screen
     end
   else
     begin
      Set success to false;
      Display message
     end;
end{GetNewScreen};
```

Figure 3.16 Pseudo-code procedure for obtaining next screen

The flow of control for the display of information screens is illustrated in Figure 3.17. As can be seen from this diagrammatic representation of the information network, it consists of an arbitrarily complex network of screens.

Further reading and index screens are not functionally different from any other standard information screen. The further reading screens do not generally contain any active areas, and return to the main information network is via the back-one facility. Index screens consist of a large number of active areas underlying the brief titles or descriptions of information screens or tour starting points (Tours are marked by a bracketed "T" after their descriptive title).

3.5.3 Back-one protocol

As the name suggests, this bottom line box facility permits the re-tracing of all screens viewed. Figure 3.18 shows a typical path through a network. Notice that the entire path to the start of the current session is permitted, even though the start screen has been visited a number of times. The back-one facility affects the tour and quiz modes as discussed later. Map screens are updated correctly (that is they show the correct footprinting of all screens visited) as they are re-drawn on a *back-one* path.

3.5.4 Restart protocol

This facility permits the immediate display of the start screen. It is illustrated in Figure 3.18. All tour and quiz modes are terminated.

3.5.5 Exit protocol

The program can only be terminated by activating the "End Session" bottom-line box, and then choosing the appropriately labelled active area on the exit screen. This active area sets the current screen code variable to “999”, which is the internal code for terminating the program. This two stage process of termination is illustrated in Figure 3.17. From this last screen, it is possible to invoke back-one and restart in order to continue using the program. If a quiz is in progress, then it is turned off on accessing the last screen. If the system is in help or tour mode then the "End Session" box is labelled "Leave Help" or "Leave Tour" respectively. The action now is to return to the last screen viewed prior to entering help or tour mode.

This exit screen is also activated if there has been no button activity for a specified period of time (usually set to five minutes). If there is still no user activity after a similar time period, then the program is terminated and an error code returned to the parent program. This function is performed by the **Procedure** *watchdog* called from within the mainloop module.

3.5.6 Map screen protocol

Map screens provide a spatial representation of part of the network, and are another form of navigational tool. Each node of the map may be used to access information screens (or another map). In this respect, they are functionally no different to other information screens. However, they show, by highlighting, the appropriate nodes of those screens that have previously been visited and, if applicable, the screen from which the map screen was invoked by a different form of highlighting. This action is illustrated in Figure 3.19. The background colour of each rectangular active region on the map screen, corresponding to each node of the map, is set to logical colour 3 with the overlying text in logical colour 0. If a node corresponds to the screen from which the map facility was invoked, then the region is set to logical colour 1. If a node corresponds to any other previously visited screen, it is set to logical colour 2. Due to the limited range of colours available and the need to maintain good contrast between text and the underlying fill, then great care has to be taken in selecting the screen colours. A stack, with the head pointer *maplink*, is maintained which records all screens visited. This stack is searched in order to display the correct footprinting on map screens. As noted in Section 3.5.2, retracing the path through the network, using the back-one facility, will correctly display the map footprinting.

3.5.7 Help module protocol

The on-line help facility consists of a module of information screens describing the various facilities and navigational tools available. The linkages between help screens is as normal, but there is only one route available for accessing help information - namely by activating the "help" bottom-line box. The "End Session" box is now re-labelled as "Leave Help." If this box is activated, then the user is returned to the information screen from which help was invoked. This action is illustrated in Figure 3.17. If tour or quiz modes were active prior to entering the help module, then they are placed into a dormant mode (see following sections).

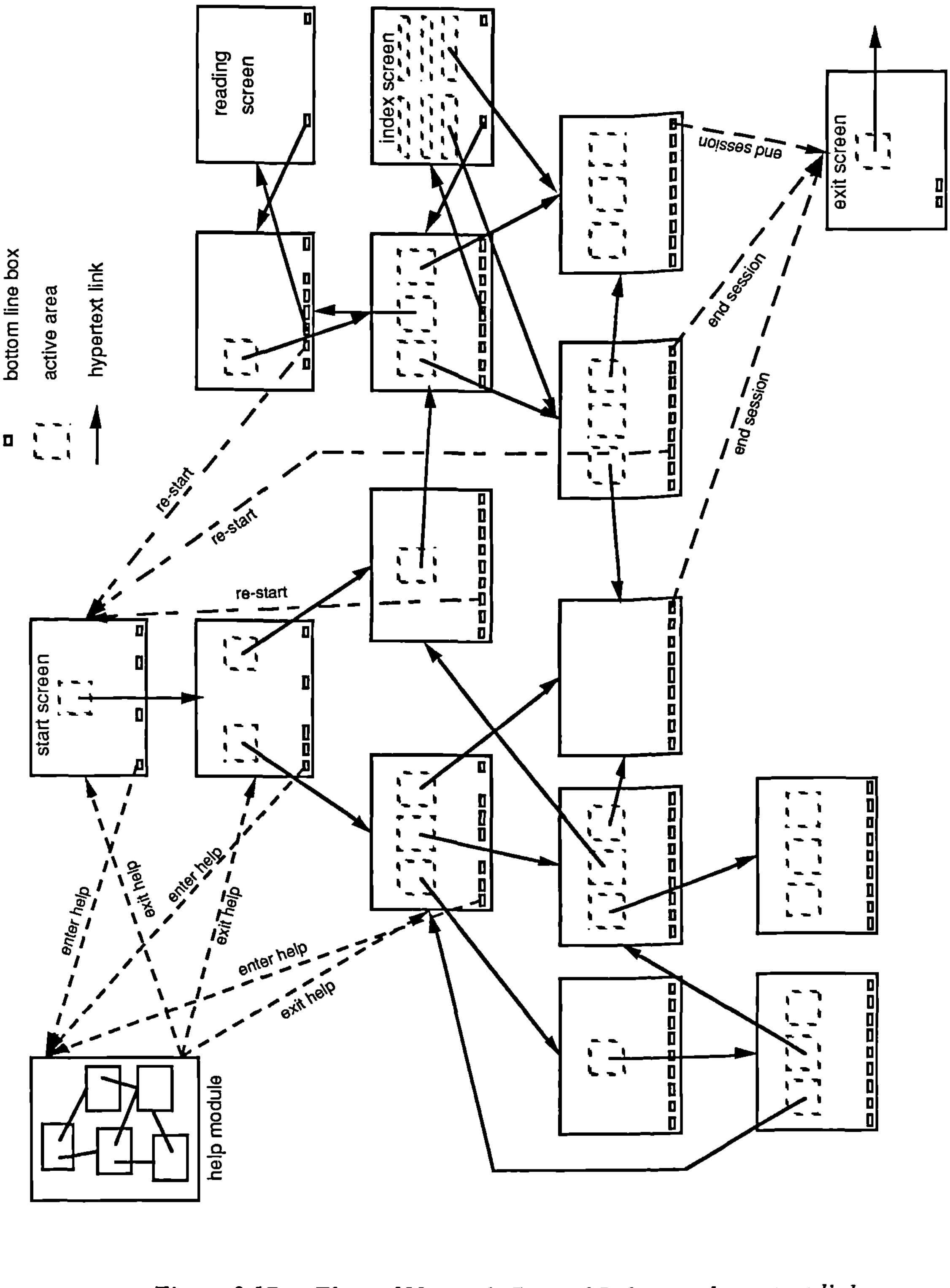


Figure 3.17 Flow of Network Control I shows:- hypertext links, restart, exit and help modes

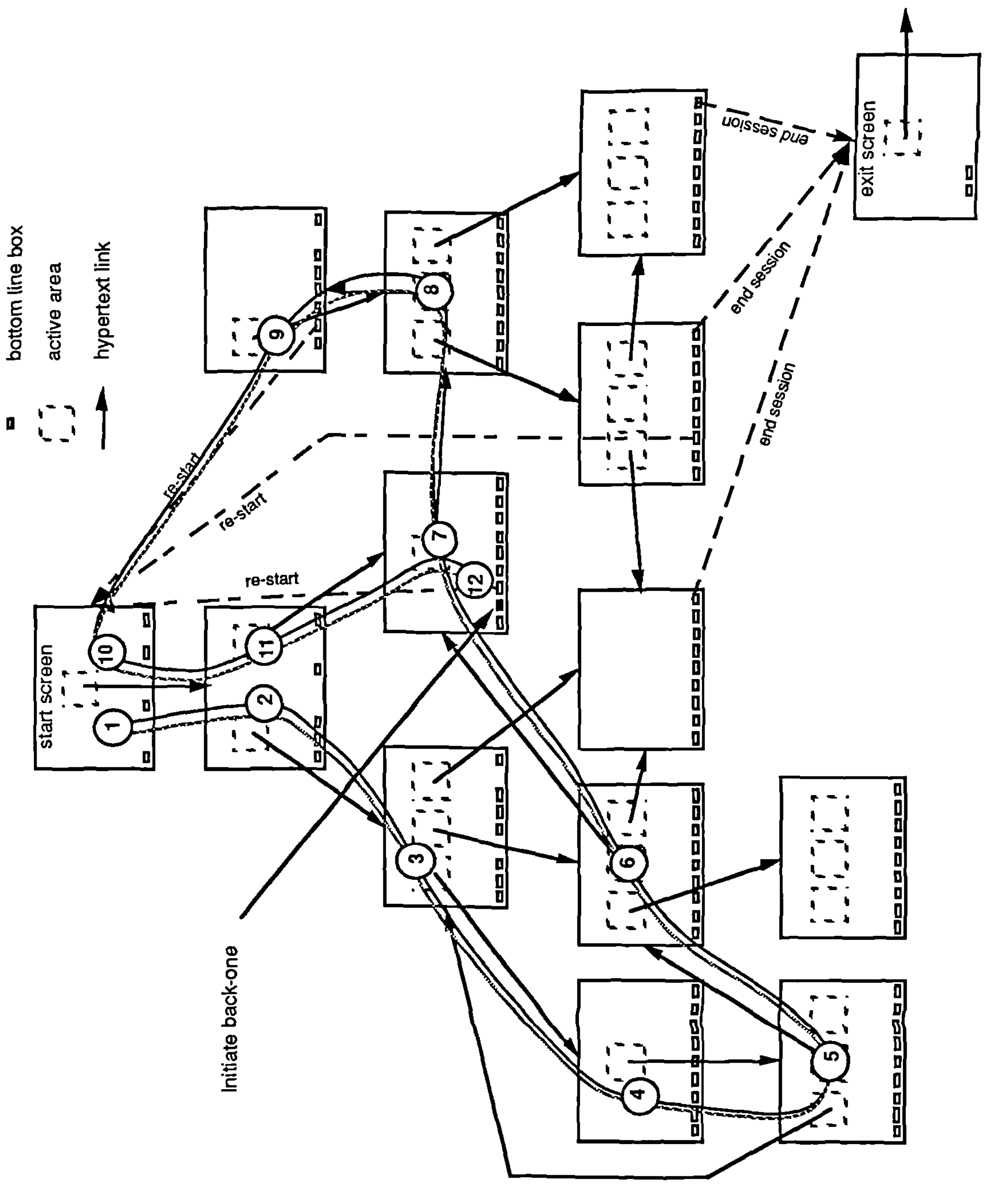


Figure 3.18 Flow of Network Control II shows:- activation of back-one facility

3.5.8 Guided tour protocol

The incorporation of guided tours into the **LINKER** program was one of the most significant developments, in that it provides a structured navigational facility by which users can view a pre-determined sequence of information screens, and it also represented a great deal of development effort before the final functionality was implemented. Chapter 2 has examined this development of guided tours; this section will detail the final state of implementation.

Tours can only be instigated by activating an active area, which possess a `ScreenCode element` with a value between 1000 and 2000. These are clearly identified in the information screen by a textual description concerning the material covered by the tour and a graphical representation of a coach. This *high* value of the `ScreenCode` variable initiates the tour mode. The functionality and visible effects of guided tours is explained with reference to Figure 3.20 and the description of actions and events is given in Table 3.2.

As can be seen from the above, the implementation of guided tours, though presenting an unified, explicit and simple interface to the user, requires a considerable amount of software control. The following paragraphs detail some aspects of this implementation.

The external **TOUR.$** files consist of a file of integers – each representing the next screen on the tour. Tours are circular, in that they end on the same screen as they commenced from. The file data is transferred into the tour queue. Every time the *Next* bottom-line-box is activated, the top item of this queue is popped off, and becomes the screen code for the next screen to be displayed. In fact two items are popped, in order to check if the queue is empty and the end of the tour has been reached. The second item (if not **nil**) is pushed back. If the user leaves a tour, then the *current screen* code is pushed on to the queue, so that on re-joining the tour, the last tour screen visited is displayed. The tour files are maintained in a separate directory to screen files.

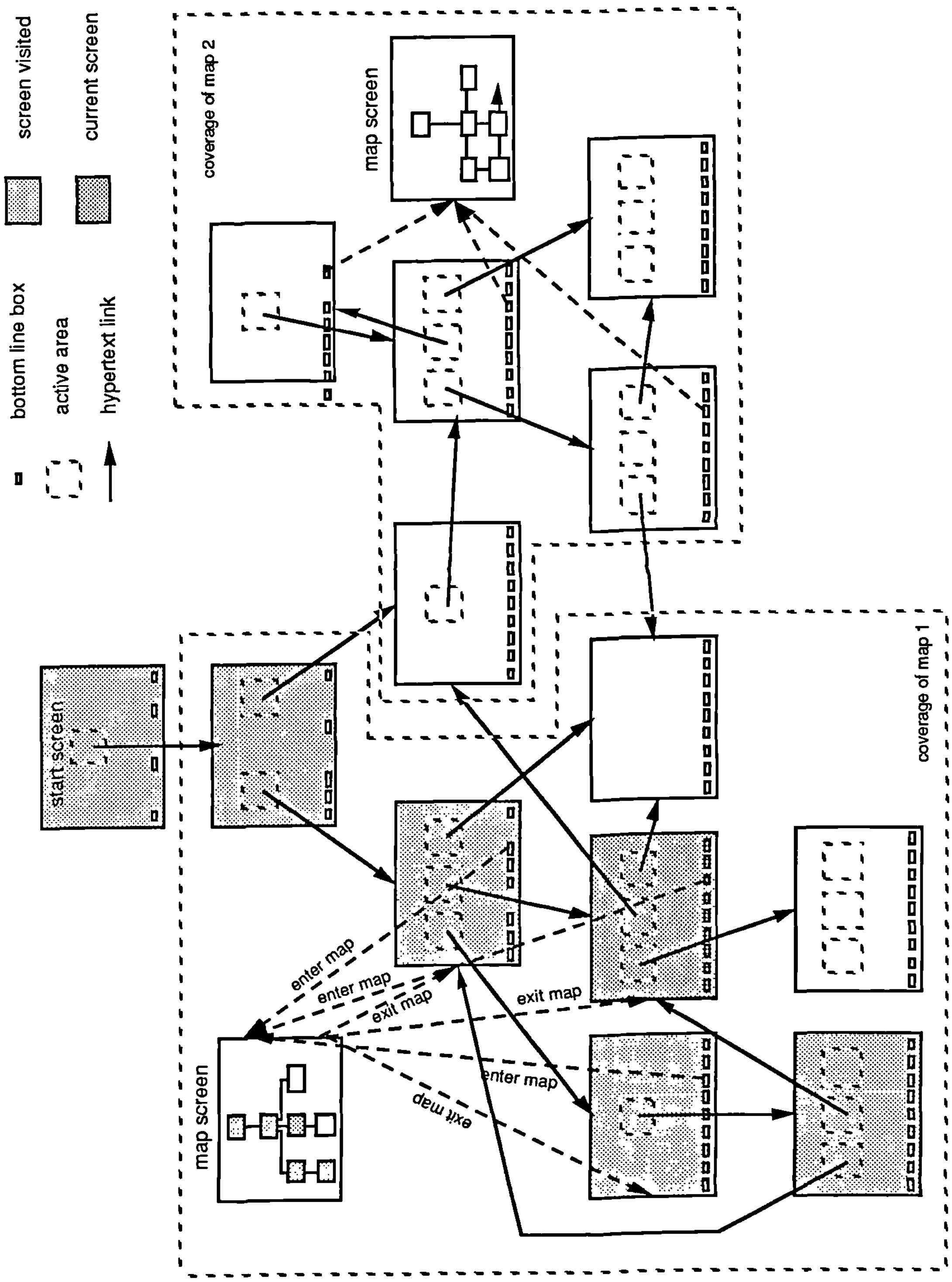


Figure 3.19 Flow of Network Control III shows:- action of map screens

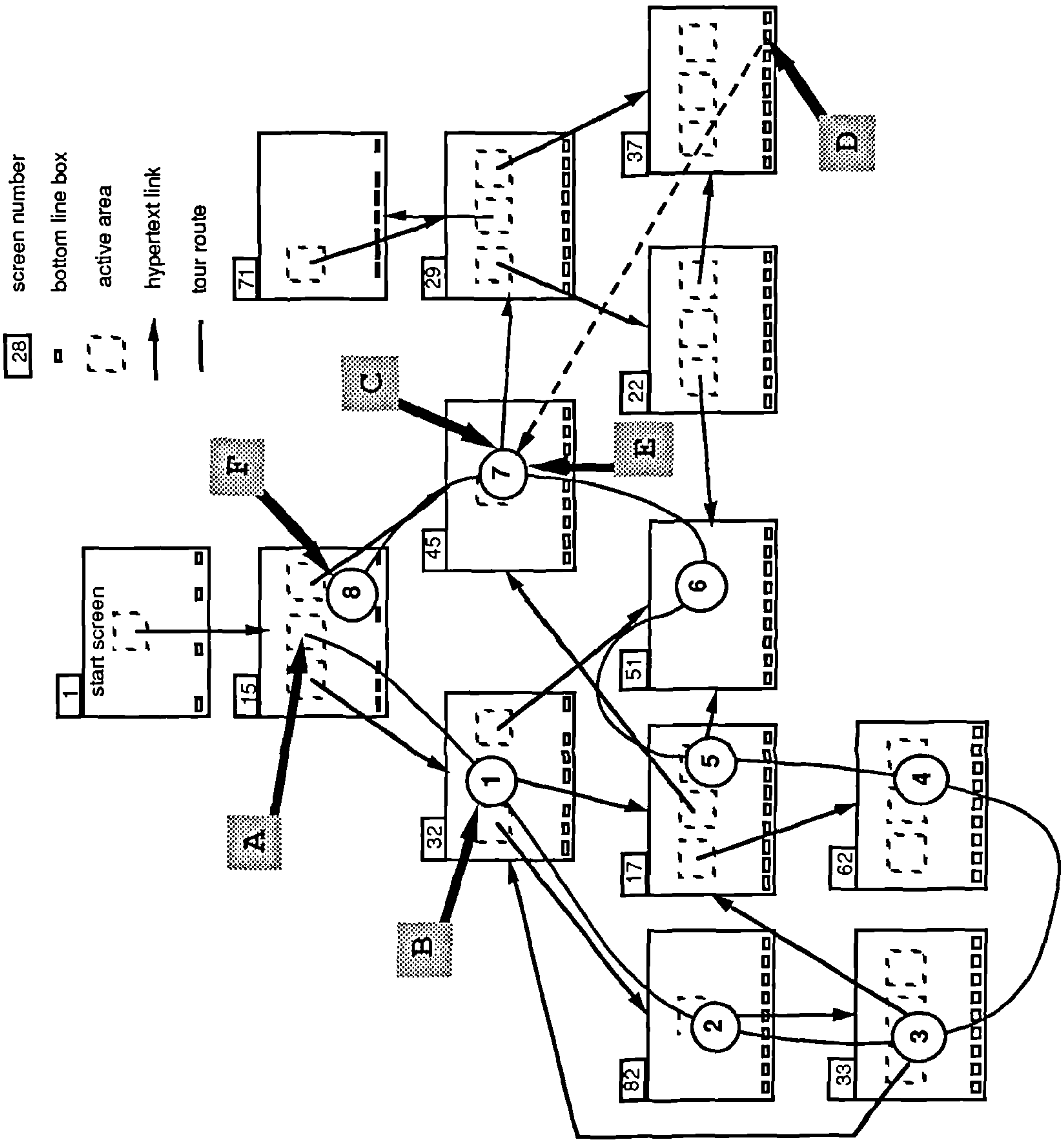


Figure 3.20 Flow of Network Control IV shows:- action of guided tours

Table 3.2   Tour Functionality

	User Action	System Action Internal	System Action Interface
A	Selects *Start of Tour*	Gets tour file Sets *tourstatus* to on Creates new tour queue (32,82,33,62,17,51,45,15) Get first tour screen(32)	Displays first tour screen Changes mouse icon to *coach* Displays *Next* bottom-line-box
B	Selects *Next* bottom-line-box Continues on tour	Get second tour screen(82) Get subsequent tour screens	Displays second tour screen Displays subsequent tour screens
C	Selects active area on screen Continues through network	Sets *tourstatus* to off Push last tour screen onto tour queue (ie, 45) Get selected screen (29) Get selected screen	Displays selected screen Changes mouse icon to *pointer* Display *Tour* bottom-line-box Changes *Leave Tour* to *End Session* Displays selected screen
D	Selects *Tour* bottom-line-box	Sets *tourstatus* to on Pop first tour screen off queue (ie, last tour screen visited) Get tour screen (45)	Displays tour screen Changes mouse icon to *coach* Displays *Next* bottom-line-box
E	Selects *Next* bottom-line-box	Tour queue detected as empty Sets *tourstatus* to never Activates any tour previously in progress Get last tour screen(15)	Displays last tour screen Changes mouse icon to *pointer*
F	(At end of tour) Continue....	Returns to 'start' screen of tour	Changes *Leave Tour* to *End Session* Changes mouse icon to *pointer*

The procedure of Figure 3.21 is invoked in the first conditional statement in **Procedure** *TakeAction*, that is before the new screen is loaded and displayed.

```
Procedure StartTour (var ScreenCode,effect:integer; var success:boolean);

begin
  Change file directory to "c:\tours";
  If external file TOUR.{1000 - ScreenCode} exists then
    begin
      Assign TOUR.{1000 - ScreenCode} to internal file tourfile;
      Clear previous tour queue;
      Create new tour queue;
      Set tourstatus to on;
      Set effect to 9{i.e., tour};
      If quizstatus is active then
        begin
          Set quizstatus to sleeps;
          Note last QuizScreen(for eventual return)
        end
    end
  else
    begin
      Set success to false;
      Display message "Tour not available in this session" for 2.5 seconds
    end{If external file...};
  Change file directory back to "c:\"
end{StartTour};
```

Figure 3.21 Pseudocode procedure for starting a tour

Since the variable `effect` now has the value of "8", the main *case* statement of the `Procedure TakeAction` will select the `Procedure GetNextTourScreen`, as shown in Figure 3.22.

```
Procedure GetTourScreen;

begin
  If tourstatus is on or was then
    begin
      Pop next ScreenCode off tour queue;
      If at least one more screen in queue then
        begin
          Set tourstatus to on;
          GetNewScreen(ScreenCode)
        end
      else
        begin
          Set tourstatus to off;
          Clear tour queue;
          If quizstatus is sleeps then
            Set quizstatus to on;
          GetNewScreen(ScreenCode)
        end
    end
end{GetTourScreen};
```

Figure 3.22 Pseudocode procedure for obtaining next tour screen

These two procedures control the initiation of tours. Other procedures are called that switch off tours if a user diverts by selecting an on-screen active area. The tour can be joined, as explained above, by selecting the *Tour* bottom-line-box. However, a further facility exists that permits the re-joining of a tour. If a user after diverting from a tour and directing his own path through the network of information screens, activates a screen which is the same as the last tour screen he visited or the next tour screen to be visited after this one, then the tour is re-activated. They can, of course, ignore this prompting and continue to follow their own route. The procedure of Figure 3.23 is called every time a new screen is about to be loaded. Procedures that handle the display of the bottom-line-boxes and the mouse icon possess conditional statements that respond to the status of *tourstatus*, and respond accordingly.

```
Procedure TourCheck(var ScreenCode:integer);

var
  ok:boolean;
  acode,bcode:integer;

begin
  If tourstatus is on then
    begin
      pop acode off tour queue and check queue not empty (ie, ok is true);
      If (acode = ScreenCode) and ok then
        set tourstatus to on
      else
        begin
          pop bcode off tour queue;
          If (bcode = ScreenCode) and ok then
            set tourstatus to on
           else
             push bcode back on queue;
           If tourstatus is not on then
              push acode back on queue
          end
    end
end{TourCheck};
```

Figure 3.23 Pseudocode procedure to check possible tour status on loading new screen

3.5.9 Quiz protocol

The quiz mode can only be entered by activating the Quiz bottom-line-box, where one is available. Quiz screens consist of a question and a number of suggested answers (usually four) – one answer is the correct one and the remainder incorrect. On selecting the correct answer, the next screen displayed confirms this choice as correct or otherwise, provides some extra information and permits the user to attempt another question via the Quiz box, or to leave this mode via the Leave Quiz box. On selecting an incorrect answer, the next screen announces this together with some helpful information. The user can divert into the information network so that the screen describing the background to the question is displayed. This flow of control is illustrated in Figure 3.24. The user may traverse any number of information screens, and is always offered the choice, through bottom-line-box selection to re-join the Quiz. If the user selects the latter, then they are returned to question screen they last attempted to answer.

The quiz mode is switched off on selecting re-start and put into a dormant mode if a guided tour is activated. On progressing through the network via the back-one facility, then quizzes are re-activated and the appropriate bottom-line-boxes appear.

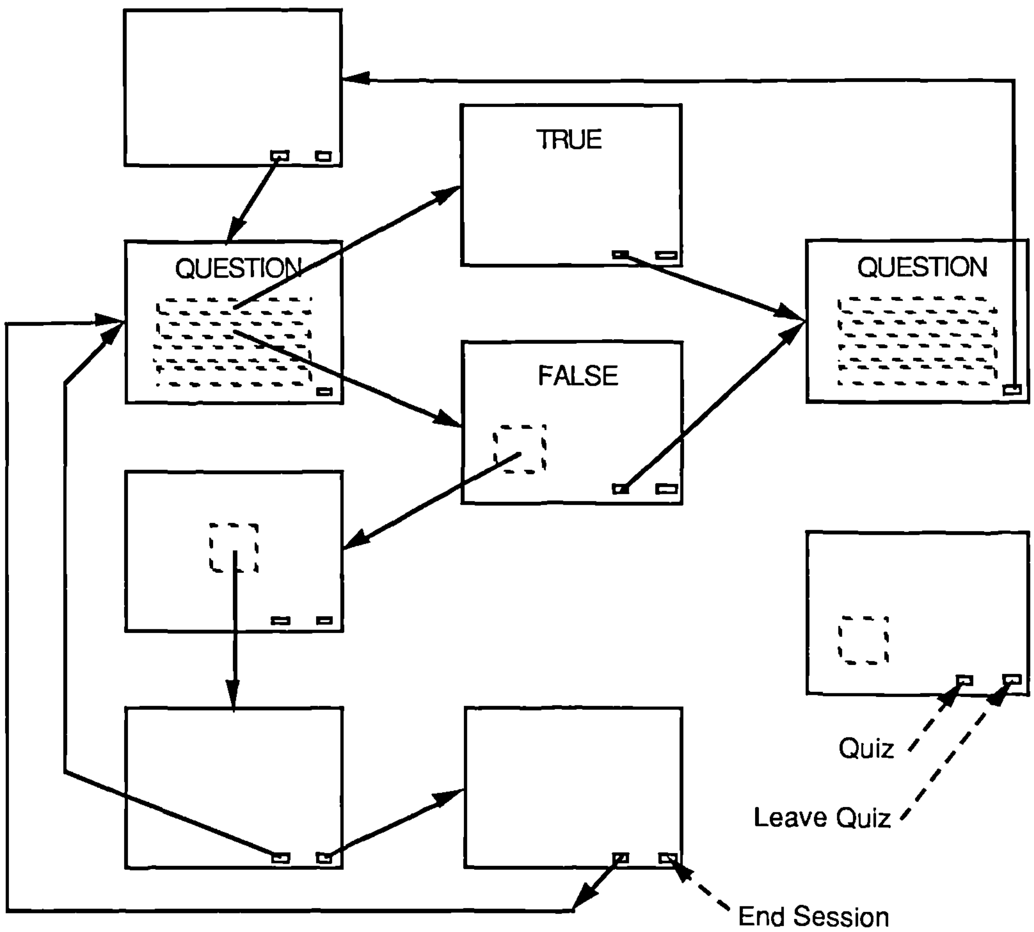


Figure 3.24 Flow of Network Control shows:- action of quiz protocol

3.6 Timing Considerations

There are a number of occasions where accurate timing of screen displays and mouse activity are required (for example, in the demonstration of various memory effects). The current time is obtained by a supplied Pro-Pascal procedure, which is an extension to standard Pascal and makes use of the internal real-time clock of the computer. This procedure is declared as:–

```
Procedure time (var hours, minutes, seconds, hundreds:integer);
```

All timings internal to the program have a limiting resolution of $\frac{1}{10}$ second. Any attempt to use finer resolution would be suspect, since screen refreshes occur at a rate of 25 Hz, and mouse activity can not be resolved at a $\frac{1}{100}$ second resolution due to program execution speed. Hence internally current time is expressed as:–

```
CurrentTime:=10*(seconds+60*(minutes+60*hours))+trunc(hundreds/10);
```

It is necessary to safeguard all timings from the cyclic nature of the 24 hour clock (Someone may use the system around midnight!). This is illustrated in the procedure given in Figure 3.25, which implements a specified pause.

```
Procedure pause (duration:integer);

var
  init,final:integer;

begin
  init:=CurrentTime;
  repeat
    final:=CurrentTime;
    if final < init then
    {protect from 24 hour clock}
      final:=final + 864000
  until final >= (init + duration)
end{pause};
```

Figure 3.25 Procedure to initiate a specified pause - note 24 hour clock protection

3.7 Interactive Control

3.7.1 Introduction

Originally, the presentation software adhered to the philosophy of navigation around a pre-defined network of pre-defined screen displays. This leads to a number of obvious limitations, which may be illustrated by the following scenarios:–

- Keeping a score for the quiz facility and hence providing users with this score as a form of informative feedback. For example, "You have answered 6 out of the 12 questions correctly".

- Providing information about the number or type of screens visited. For example, "You have visited 7 out of the 20 screens in the Memory Module".

- Modifying the subsequent routing of screens depending on user responses to quizzes or which screens had previously been visited. For example, can only go to screen X if screens Y and Z have been viewed.

- Providing the results from the in-built experiments. For example, the need to record user choices and reaction times, to compute averages and percentages, and to display results in tabular or graphical form.

In order to provide these facilities, it is necessary to declare suitable data structures to which interactive variables can be assigned. The storage of these variables, which are defined at run-time, is a 51-element array, **varray**, namely:–

```
plusint = 0...32767;
varray : array[0...50] of plusint;
```

The first array element, varray[0], has a special purpose as it is used to redirect screen routing. Before the next screen is loaded the following test is performed:–

```
If (varray[0] > 0) then
  begin
    next screen number set to varray[0];
    varray[0] set to zero
  end;
```

The sequencing as to when variables are set and the resultant arithmetic performed within **LINKER** is as shown in Figure 3.26.

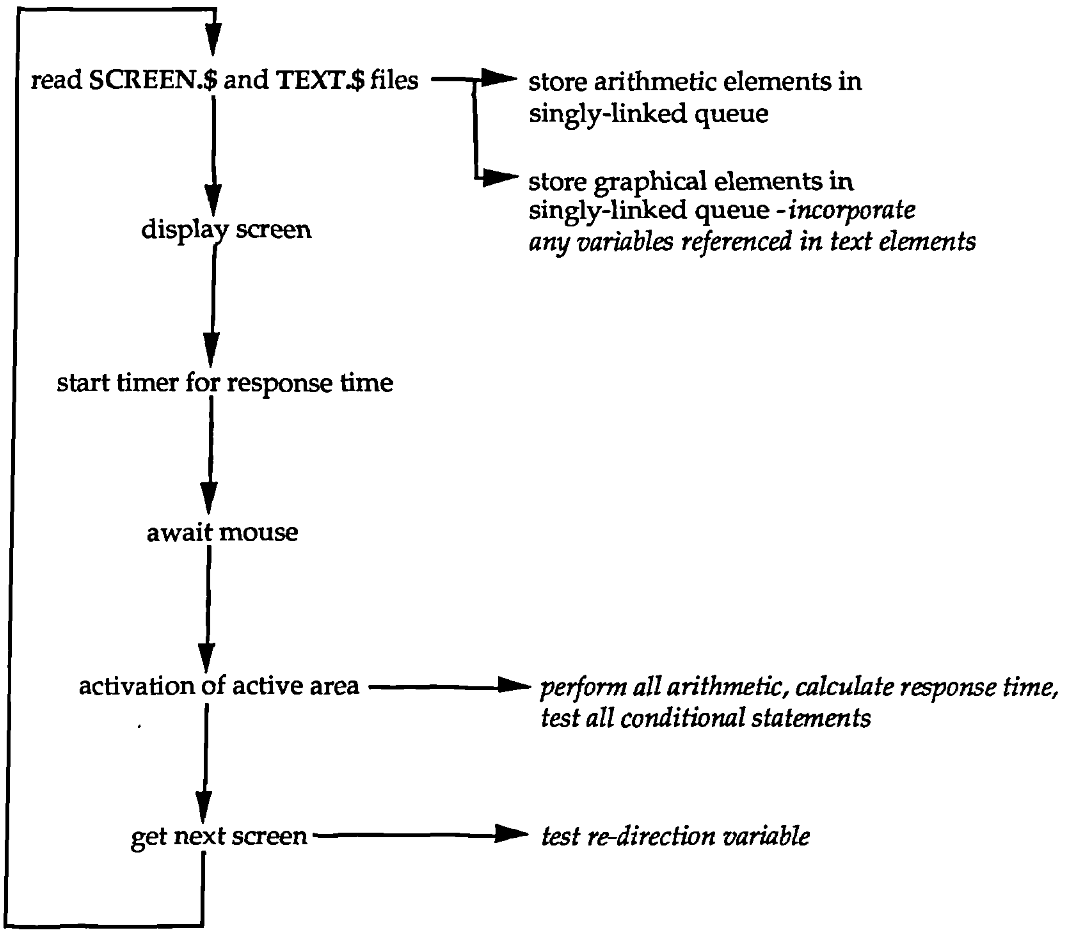


Figure 3.26 Variable sequencing

3.7.2 Implementation of arithmetic elements

The general form of all arithmetic elements, in the **SCREEN.$** files, is:–

```
arith(opcode,p1,..., pn),
```

where `opcode` is the operation code and p1,..., pn is a parameter list.

If the parameters are negative, then they refer to the elements in the varray, for example, if p1 = -6 then p1 is set to the value of varray[6]. The absolute position of `arith` elements in the **SCREEN.$** files is unimportant, however their relative position is critical. Details of how these elements are declared in the screen files are described in the later sections on **PED**.

3.7.3 Arithmetic functions available

The general form is:–

```
arith(opcode,p1,p2,p3) ≡p1 := p2 opcode p3,
```

for example, `arith(2,-6,-4,23) ≡ varray[6] := varray[4] - 23`
p1 must be a variable, but p2 and p3 can be either variables or constants. All arithmetic is of integer format, and is fully protected for under- and over-flow errors.

The following opcodes are implemented:–

opcode	action
1	+
2	-
3	*
4	div
5	mod
6	max
7	min

3.7.4 Conditional functions available

The general form is:–

```
arith(opcode,p1,p2,p3,p4) ≡ p1 := p2 iff p3 opcode p4,
```

for example, `arith(129,-8,-14,48,-1) ≡ varray[8] := varray[14] iff 48 > varray[12].` p1 must be a variable, but p2, p3 and p4 can be variables or constants - though `arith(128,-12,18,23,25)` is meaningless but valid.

The following opcodes are implemented:–

opcode	action
128	=
129	>
130	<
131	<>
132	<=
133	>=

3.7.5 Clear function

All the varray elements are set to zero by using:–

```
arith(126, .....);
```

The parameter list is ignored. All variables are set to zero at start up, but after this they can only be changed by explicit arith commands.

3.7.6 Response time measurements

It is possible to time the period from the completed display of a screen to the next mouse button press. `Arith(127,px)` will set the varray[px] element to this time interval to a $\frac{1}{10}$ second resolution. If the interval is greater than 3276.7 seconds, then it is set to this maximum time.

3.7.7 Text display of variables

If, for example, the **`TEXT.$`** entry corresponding to a text element in the next screen to be loaded contains the line "You have achieved a score of @3@ in the last quiz" then

"@3@" is replaced by the value of varray[3]. An example which combines the last two functions is:–

```
arith(time,p1)                  p1 := 386 (say)
arith(div, p2, p1, 10)          p2 := 38
arith(mod, p3, p1, 10)          p3 := 6
```

If the text screen's **TEXT.$** file includes "You took @2@.@3@ seconds to complete the task" then the displayed text will be "You took 38.6 seconds to complete the task." Hence "@" is a reserved symbol in all text entry.

3.7.8 Next screen access

If a constant is set to 32767 in any arith element then it is replaced at run-time by the current screen code. For example:–

```
p0 := 84 iff CurrentScreen code = 49,
```

that is, the next screen code is number 84 if the current screen code is 49. This is expressed as:–

```
arith(128,0,84,32767,49)
```

A more complex example is:–

```
p3 := 1 iff current screen code = 56
p4 := p4 + p3
p5 := 1 iff current screen code = 65
p6 := p6 - p5
p0 := 100
```

This is a method of increasing a quiz score depending on active area selection. In this example, if the active area 56 is chosen, then p4 is increased by one; if active area 65 is chosen, then p6 is decremented by one. But the next screen will be 100 regardless. This can be entered as:–

```
arith(128, -3, 1, 32767, 56)
arith(1, -4, -4, -3)
arith(128, -5, 1, 32767, 65)
arith(1, -6, -6, -5)
arith(1, 0, 100, 0) {i.e., p0 := 100 + 0}
```

3.7.9 Mouse location

Normally the initial position of the mouse pointer on a new screen is the last position on the previous screen. For experiments which measure reaction times then a means of setting the pointer to a specified location is required. This achieved by invoking:–

```
arith(125,px,py);
```

where px and py are the desired x and y co-ordinates respectively.

3.7.10 Automatic graph generation

Two dimensional graphs can be generated with scaled ordinate values determined at run time; all abscissa co-ordinates are fixed. The ordinate values are derived from a consecutive group of variables in the varray. Defining the range of input variables and output variables (i.e., screen co-ordinates) as follows:–

```
Range of input variables      w_min <= w <= w_max
Range of output variables     y_min <= y <= y_max
```

Then the mapping is given by:–

```
y := scale_factor * w + offset
```

Where, `scale_factor :=` $\frac{(y\_max - y\_min)}{(w\_max - w\_min)}$

`offset :=` $\frac{(y\_min * w\_max - y\_max * w\_min)}{(w\_max - w\_min)}$

This graph function is invoked by a graph element in the graphical element queue. The form of this element is:–

```
graph(pm, n, w_min, w_max, y_min, y_max),
```

where

pm	– first variable in varray referenced, i.e., varray[pm]
n	– number of variables referenced, i.e., up to varray[pm + n - 1]
w_min, w_max	– input range
y_min, y_max	– output range, i.e., screen co-ordinate range

A graph element must precede, in the queue, either box or line elements; this determines the type of graph drawn – histogram or line. The box or line elements are defined in the normal manner in **PED**, since they include no information concerning their variability. The output range is limited from `y_min` to `y_max`, so that there is no over- or under-flowing of the graph. Multiple graphs, either separate or composite, may be produced on the same screen but the graph element must in each case be proceeded by suitable box or line elements. The form of a typical histogram graph is shown in Figure 3.27.

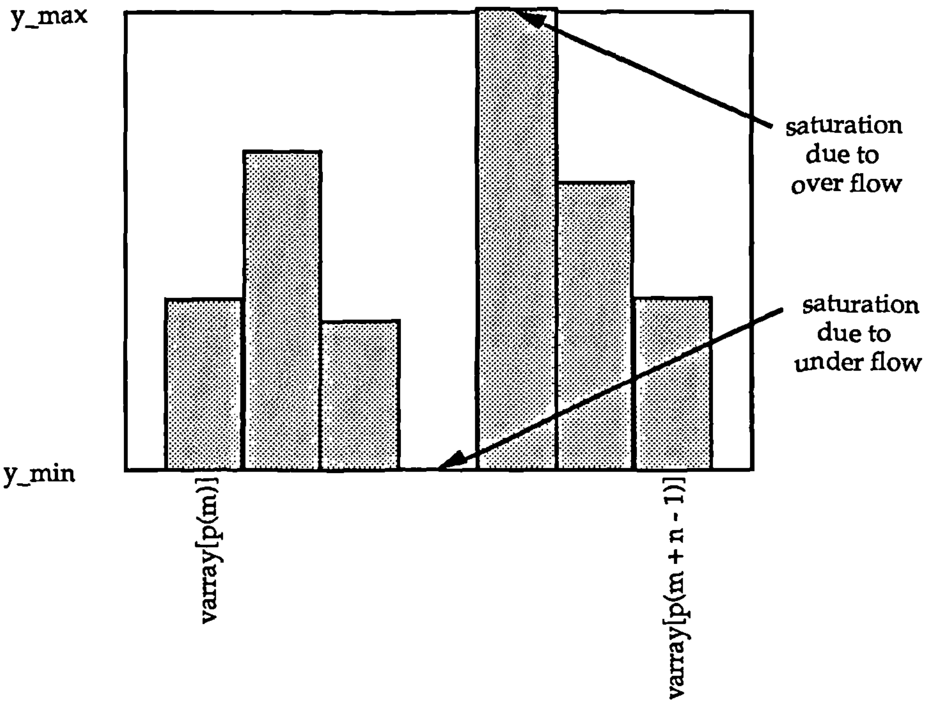


Figure 3.27 Automatic Graph Generation

3.8 Directory Handling

As the number of information screens increased, then difficulties arose in maintaining acceptable response times between the user selecting an active area and the resultant screen being drawn. This was due to excess search times for files in what had become a very large directory. The MS-DOS directory structure is shown in Figure 3.28. The root directory can only hold a maximum of 102 items, either files or sub-directories. All other directories have no such limit, as MS-DOS regards them as files. However, there is an advantage, in terms of access time, in providing relatively small directories. Large directories will be written over a number of disc sectors, which in turn increases disc access times. Several methods were explored to ease the problems of excessive file access times. The following paragraphs outline the final implementation of placing groups of screen, text and bit-mapped graphics files in separate directories (termed modules). The root directory is on the silicon disc associated with each network station.

Since this disc is based on a large contiguous block of RAM, it possesses very fast access, read and write times, and being local to each station does not require to use the network. The executable files for **LINKER** and **SIGNIN** reside here, together with the sprite data files, tour files and as many of the regularly used screen and text files as possible (e.g., all help module files). The user logfile is written to this disc during the execution of **LINKER**.

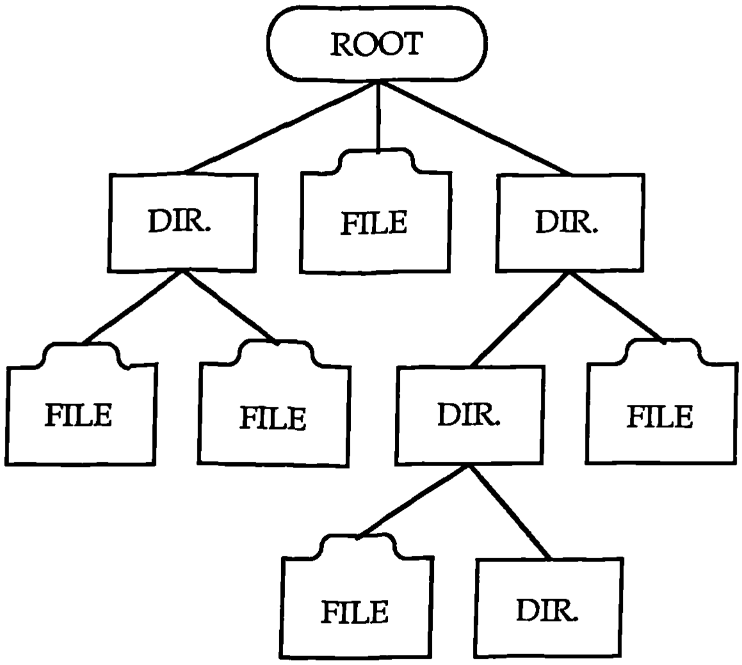


Figure 3.28 MS-DOS Multilevel Directory Structure

A file containing the location of each information screen's files is maintained on the silicon disc. This file, with internal name **modfile** and external name **MOD.DAT**, is a file of the following record type:–

```
modrec    = record
            screen:integer;
            module:char
            end{modrec};
```

The search sequence is given below in Figure 3.29. As files are grouped together by subject area in the directories on the hard disc, directory changes are normally infrequent.

However, it is necessary to change directories a number of times, from within **LINKER**. This is due to the large number of information screens available. If they are all located in a single directory then the file access time can become large since multiple directory tracks need to be searched. No facilities were provided in the Pro-Pascal language to permit this, so a machine code program had to be written. This incorporated in the Pascal source files as the following function reference:–

```
Function cdbig(var name:string):word; external;
  type
    directory:string;
    dummy:word;

  begin
    !
    !
    directory:= concat('p:\mod',module);
    dummy:=cdbig(directory);
    !
    !
  end;
```

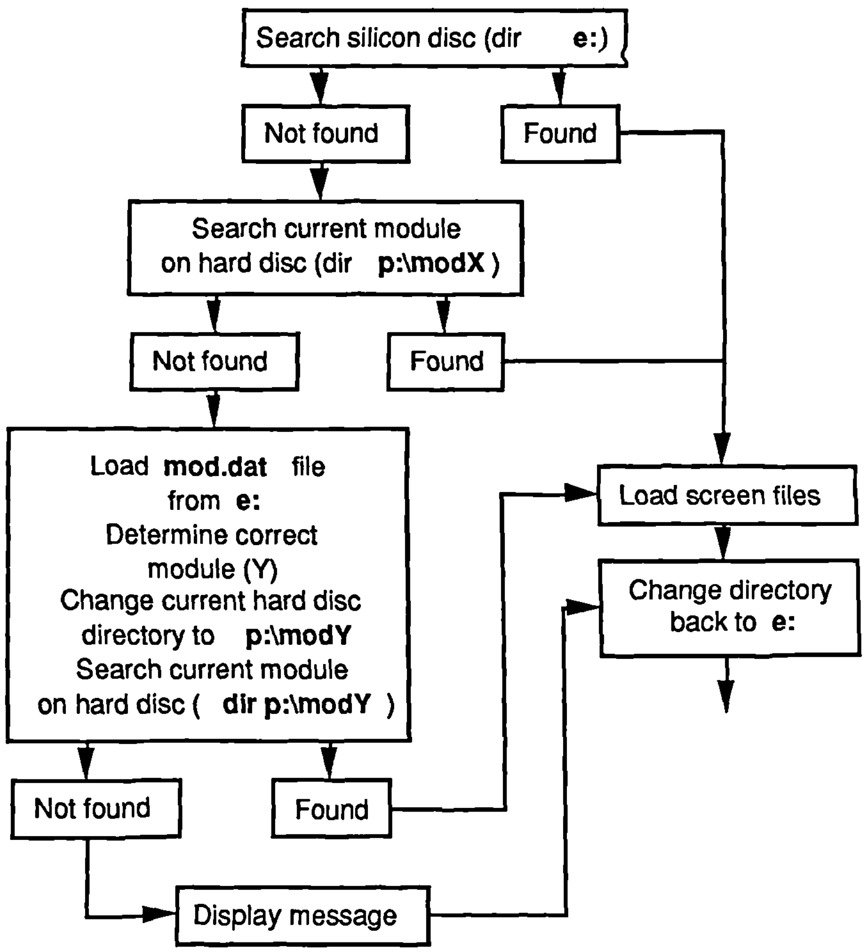


Figure 3.29 Directory Search Path

3.9 Log-file Generation

User log-files are generated that record and time all user activity. The log-file is written to the individual workstation's silicon disc, in order to minimise the file handling overheads. Only after control has been returned by **LINKER** to the parent program is this file appended to the individual user's log-file on the network server's hard disc.

Information is written to the log-file on the occasions shown in Table 3.3. Times are recorded to $\frac{1}{100}$ second. A typical segment of a logfile is shown in Figure 3.30.

Table 3.3 Log-file entries

1.	Immediately prior to display of first screen 'START', datestamp, and end-of-line
2.	Immediately after mouse button activity Single button pressed – 'B', timestamp, and end-of-line Both buttons pressed – 'A', timestamp, and end-of-line
3.	Immediately after display of new screen Current effect code, current screen code, timestamp, and end-of-line The effect codes are designated as follows:- 0: Next 'N' 1: Help 'H' 2: Previous 'P' 3: Re-start 'S' 4: Index 'I' 5: Reading 'R' 6: Exit 'E' 7: Map 'M' 8: Quiz 'Q' 9: Tour 'T'
4.	Immediately after exit from exit screen 'F', timestamp, and end-of-line
5.	Immediately after assigning new directory module (if applicable) 'Module.',modid, and end-of-line

```
START   19- 8-1988
N       1         14 48  5.54
B                 14 48  8.80
I       300       14 48 11.00
B                 14 48 13.80
N       70        14 51  2.13
B                 15 03 13.21
T       71        15 05  4.00
B                 15 11 16.81
T       72        15 23  7.84
B                 15 31 25.05
P       71        15 32  9.33
|       |         |
|       |         |
|       |         |
E       400       15 54 11.86
B                 15 54 12.84
F                 15 54 12.85
```

Figure 3.30 Typical Logfile Segment

3.10 Authoring Software

The main authoring software is the Picture Editor (**PED**). **PED** is an object-based drawing package, which not only permits the generation and positioning of individual graphical elements to produce a single information screen, but also provides the means of entering active areas (i.e., positioning, size, type – ordinary link/ tour link, code number), entering bottom-line boxes, setting the screen colours, editing existing frames and viewing animation effects.

PED is a more ambitious software program than **LINKER**, and unfortunately it was never taken to such a high state of development. Our intention in this project was not to develop a suite of software programs of commercial quality, and to have devoted more effort and time to this aspect would have put at risk the primary research goals. However, **PED** does remain a fully functional and workable facility that has been successfully used by a number of people.

The following sections will only discuss the facilities provided by **PED** and its basic functionality, and no attempt will be made to introduce implementation issues.

3.10.1 User interface

Great care was taken to ensure that **PED** presented an easily understood and efficient interface to the user. As far as possible command entry was via function keys (identified as <F1>, ..., <F10> in the following sections), and the positioning and sizing of graphical elements was through using the mouse and its associated buttons. It was necessary to use normal keyboard entry for text and specifying the code numbers associated with active areas and bottom-line boxes. As far as possible the functionality of the function keys was maintained as uniform as possible in the numerous editor modes. This general layout is illustrated in Figure 3.31. An on-screen help box was available at all times by pressing <F1>. If function key entry was required then the contents of this box identified the functions associated with each key. If, say, the user was in the process of drawing a graphical element, then the box contents briefly described the mouse actions available.

A single line of textual information was always displayed on screen. This was always at the top of the screen, though the intention (never implemented) was for this information line to move from the top to bottom of the screen depending on the current position of the mouse cursor. In this way the full screen could be seen. The information provided

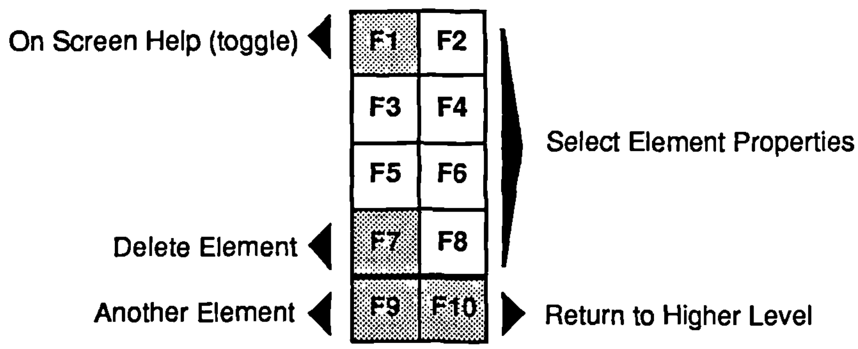


Figure 3.31 Function key assignments for all graphical element menus

consisted of identifying the current mode of **PED**, how to obtain the on-screen help and, where relevant, the co-ordinates of the cursor, the active area or bottom-line box linkage code and the next expected user action. All user input was validated, for example illegal key entries were alerted to the user by a bell sound and the possibility of over-writing an existing screen required the user to confirm their choice.

3.10.2 Overview of PED

Figure 3.32 indicates, in block diagram form, the functional modes of **PED**. On launching the application, an option is provided to allow the editing of an existing screen (identified by its screen number), or to start a new screen (screen number generated automatically as the next available uncommitted screen number). Depending on this choice, either the existing screen or a blank screen was displayed. The entry or top-level menu help box was displayed.

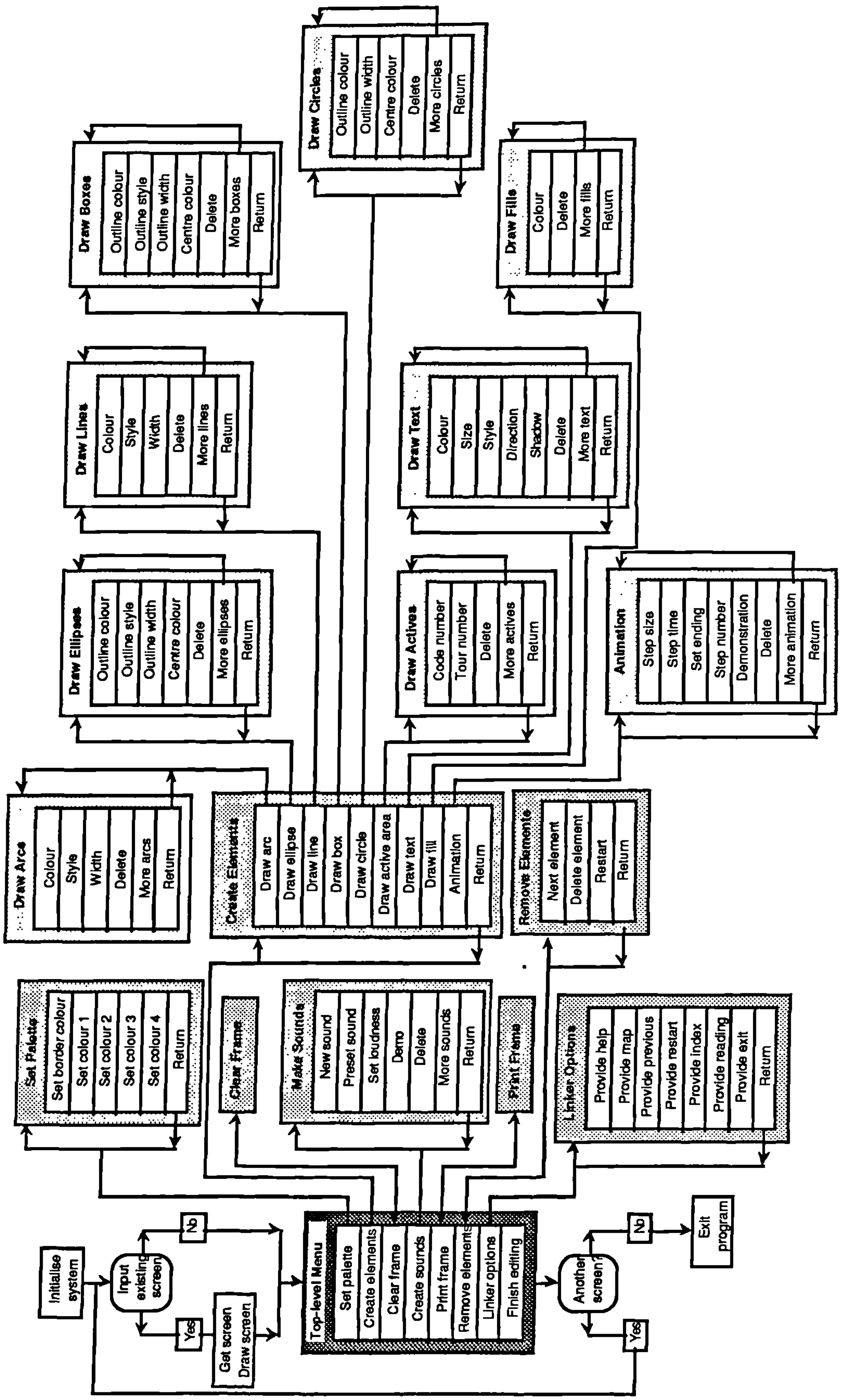


Figure 3.32 Overview of **PED**

The available facilities were:–

<F1>	Help menu ON/OFF
<F2>	Set colour palette
<F3>	Create graphical elements
<F4>	Clear screen
<F5>	Create sounds
<F6>	Print screen
<F7>	Remove elements
<F8>	
<F9>	Provide linker options
<F10>	Finish editing

The following sections will discuss, in detail, these facility modules. On entering <F10>, the completed screen and associated text files were written to disc, and the user given the option either to edit another screen or to quit the program. The program restored all graphical attributes (e.g., screen colours and resolution) to those in force before PED was initiated.

3.10.3 Colour palette module

The options available are:–

<F1>	Help menu ON/OFF
<F2>	Set border colour
<F3>	Set colour 1
<F5>	Set colour 2
<F7>	Set colour 3
<F9>	Set colour 4
<F10>	Return

As explained in Section 3.2.3, only four screen colours (referred to as logical colours - {0,1,2,3}) can be displayed at any one time from the palette of 16 physical colours available. The background colour of the screen was always set at logical colour 0, and this meant that only nine *extra* colours (through the use of 4 by 4 dithering patterns) were available. Many of the possible colour combinations were unsuitable as there was little or no contrast between various combinations. In order to assist the user, the current colour table of 13 colours was displayed as a column of 13 individually coloured squares. The four *primary* colours were identified by their respective function key code. The border colour can be, without restriction, any one of the 16 physical colours.

For uniformity of the interface, individual screen types (e.g., information, map, further reading) were always provided with a unique set of colours, and mouse-selectable text (i.e., hypertext links) was always identified by a yellow colour. These self-imposed constraints created a further restriction on the colour choices available.

3.10.4 Create graphical elements module

The elements available are:–

line
box
circle
arc
ellipse
fill
text
animation
active area

As the functionality and user-selectable parameters of these are very similar, only the box drawing module will be discussed in detail and just brief reference made to the remaining elements where differences occur. Figure 3.32 shows the structure of the "Create Elements" menu and those of the individual element menus.

3.10.5 Box drawing module

On selecting "Draw Box" from the "Create Elements" menu, then the single line information box reads:–

Box start <F5> for grid x= {*x*} y= {*y*} <F1> for help

Where {*x*} and {*y*} are the current co-ordinates of the cursor. Figure 3.33 shows a sequence of screens as a box is constructed. Figure 3.33(A) shows the situation on entry to the box drawing module when <F1> has been pressed and the on-screen help displayed. This help gives basic instructions on how to set the start and end corners of the box. If <F1> is pressed again or the cursor moved, then the on-screen help is removed. An alignment grid can be displayed by pressing <F5>, this produces a grid with horizontal and vertical major axes marked every 80 pixels (i.e., solid line) and minor axes marked every 20 pixels (i.e., dashed line). This grid is extremely useful for arranging the accurate relative alignment of graphical objects. It can be removed by pressing <F5> again.

On pressing a mouse button, a dashed outline of the box being drawn is displayed on the screen (Figure 3.33(B)). The information box contents are changed to show the current status of drawing and the on-screen help box, if activated, gives details on how to delete

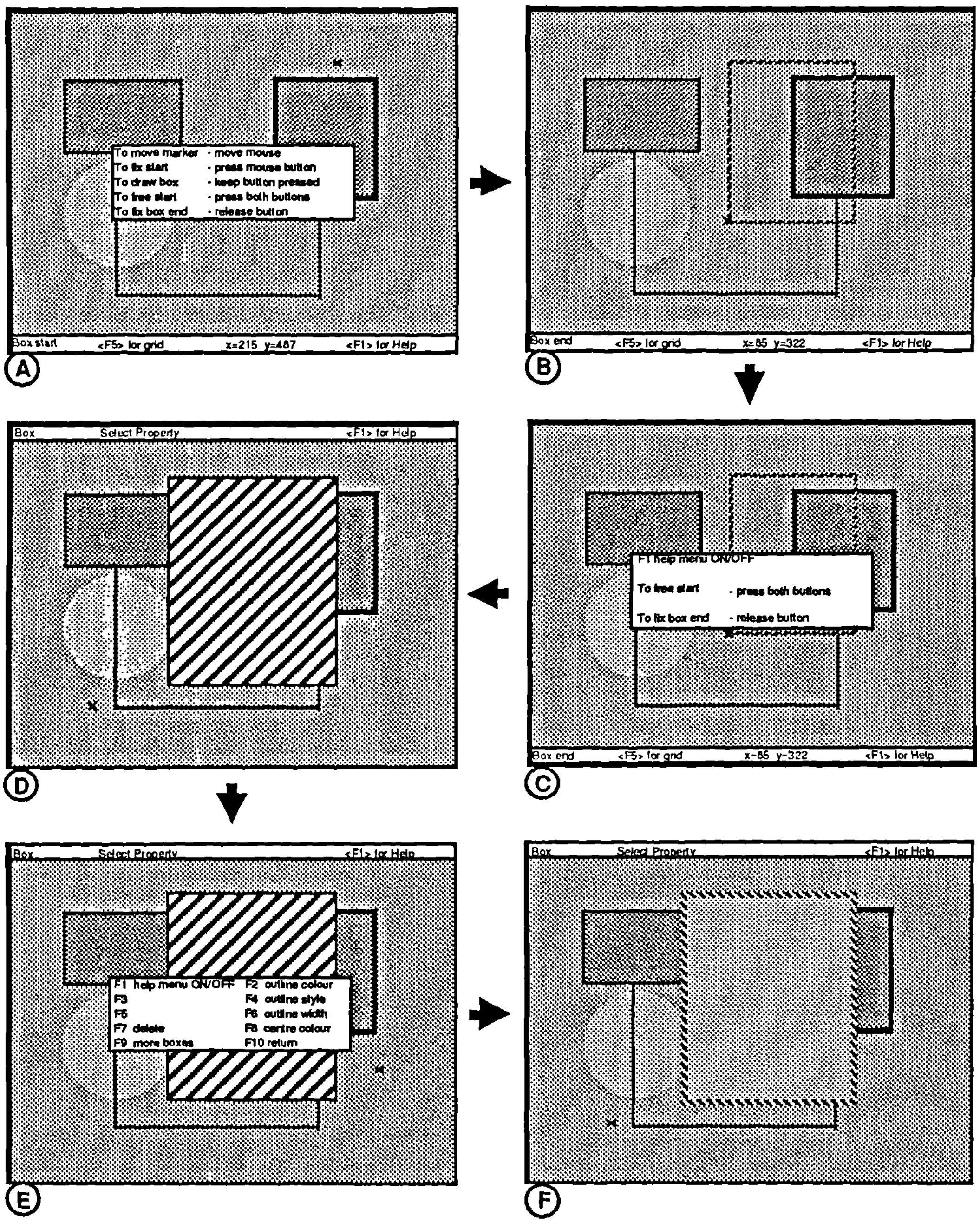


Figure 3.33 Screen sequence during box creation see text for details.

the current action or to complete the box dimensions. On releasing the mouse button, the box position and size are fixed, and the box properties (i.e., outline style, width and colour, and fill colour) are displayed in the default format (Figure 3.33(D)). The on-screen help provides details of the function key entries necessary to change these properties (Figure 3.33(E)). These properties may be changed any number of times (by repeatedly pressing the appropriate function key – the range of box parameter, for example outline colour, is cycled), or the completed box deleted (by pressing <F7>). As explained earlier the screen information was maintained as a doubly linked list of variant records within the program, and as a file of records for external storage. The latest element, though drawn on the screen, was held as a temporary record until the current module was exited or another element commenced. In this way, the latest element can easily be deleted. If <F9> is pressed then more boxes may be drawn; effectively the user is returned to the screen shown in Figure 3.33(A). If <F10> is pressed, the user is returned to the "Create Elements" level.

The graphical elements – circle, arc, ellipse, line, fill – are constructed using a similar functionality; though, of course, the number and type of properties are element specific.

3.10.6 Text drawing module

This module is more complex than the other graphical element choices, since the user has to enter text at the keyboard. So some form of input protection is required. Figure 3.34 shows a sequence of screens as text is entered. All text, though held in a separate external text file, is treated as a graphical element. Text entry is limited to a maximum of one screen line; multiple lines are entered as separate lines. Text entry is protected for all unprintable inputs and a delete facility is provided. The start of the text field is specified by the current cursor position (marking the bottom left corner of the field), and text may be re-positioned at any time during entry until the mouse button is pressed. The following text parameters are available:–

<F1>	Help menu ON/OFF	
<F2>	Colour	Four choices (4 logical colours)
<F3>	Size	Four choices (10, 20, 40, 80 characters per line)
<F4>	Style	Two choices (2 fonts)
<F5>		
<F6>	Direction	Four choices (0°, 90°, 180°, 270° to horizontal)
<F7>	Delete	
<F8>	Shadow	Four choices (plain, outline, plain/shadow, outline/shadow)
<F8>	More text	
<F10>	Return	

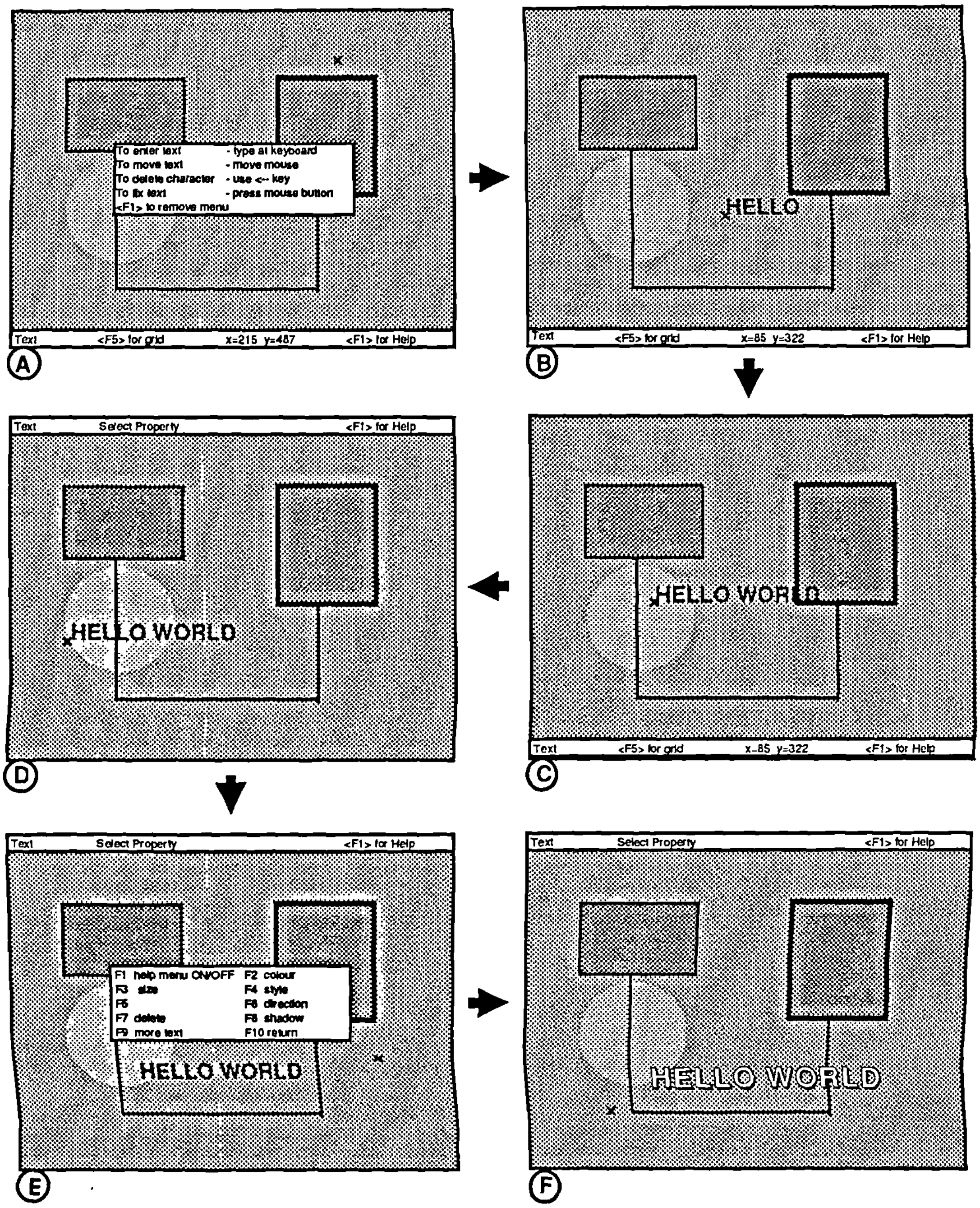


Figure 3.34 Screen sequence during text entry see text for details.

3.10.7 Active area drawing module

The initial stages in defining an active area are the same as those for defining a graphical box element. After the active area dimensions and position are fixed, the parameters available are:–

<F1>	Help menu ON/OFF
<F2>	Code number
<F3>	Tour code number
<F4>	
<F5>	
<F6>	
<F7>	Delete
<F8>	
<F9>	More active areas
<F10>	Return

If <F2> or <F3> is entered then the single-line information box will read:–

Enter active area code number --> __

or

Enter tour file code number --> __

For the case of an active area defining the start of a tour, then 1000 is added to the user supplied number. All user input is range checked (i.e., all entries must be integers between 1 and 999).

3.10.8 Animation module

The screen animation facility consists of moving a selected rectangular region of the screen over a predefined straight line path. The number of steps, and the dwell time at each step, can be specified as well whether the selected region remains on screen at the end of its path or whether it is deleted. Though fairly rudimentary, this single command permitted a wide range of screen effects as illustrated in Figure 3.35.

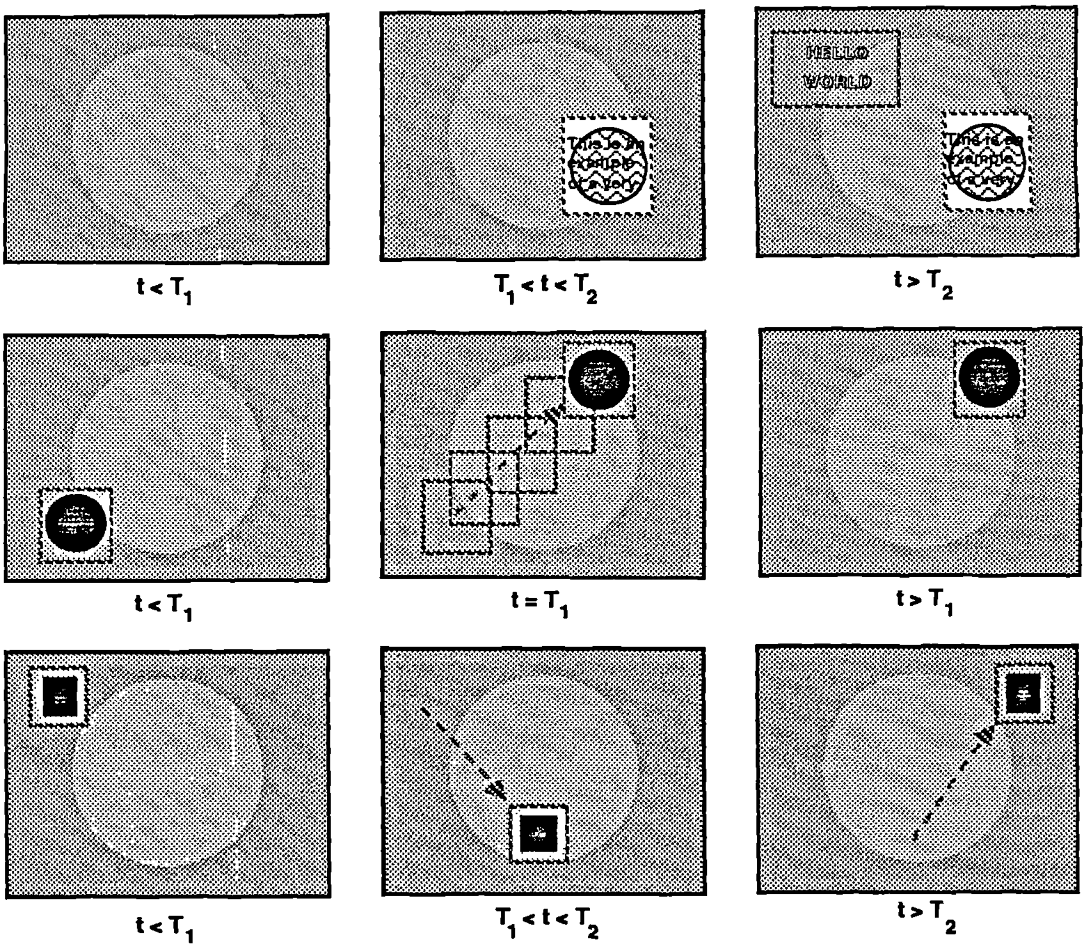


Figure 3.35 Examples of screen animation

Screen elements can be displayed after a specified time delay (all delays can be timed to a resolution of 0.1 s). Similarly, regions of the screen, which may contain one or more elements can be removed after a specified delay. Regions of the screen (selected in the same manner as described in Section 3.10.5) can be moved a discrete number of steps – each step being set in terms of changes in x and y screen coordinates and pause between steps. The following function key facilities are available:–

<F1>	Help menu ON/OFF	
<F2>	Set step size	step specified in x and y increments
<F3>	Set step time	pause between steps specified in 0.1 s
<F4>	Set ending	remain on screen or delete
<F5>	Set step number	integral number of steps
<F6>	Run demonstration	
<F7>	Delete	
<F8>		
<F8>	More animation	
<F10>	Return	

3.10.9 Print screen module

From the entry level menu, it is possible to produce a screen dump to an Epson compatible dot-matrix printer. The four logical colours are represented by a 2 by 2 matrix of dots, namely:–

colour 1	colour 2	colour 3	colour 4
oo oo	xo oo	xo ox	xx xx

where o means no dot printed and x means dot printed.

The screen dump was of acceptable quality, occupying almost the full width of printer paper together with various screen information such as its code number; however the time taken to print a single screen was several minutes.

3.10.10 Remove elements module

In order to edit existing screens, an elementary delete facility is provided. As each screen is represented as a linked list of elements, this module allowed the user to traverse the list, visiting each element in turn. The current graphical element would flash (or in the case of a sound element, it would be broadcast) and the user could select to delete the element or move to the next element. This editing facility was never extended to cope, in a sensible manner, with animation elements, as it was felt that development of a fully functional screen editing facility (with the ability to move elements in the list or to modify them) would have taken a considerable programming effort. In practice, most editing was performed on text files created from the screen files, as described later. The function key parameters available are:–

<F1>	Help menu ON/OFF
<F2>	Forward next element
<F3>	
<F4>	Backward next element
<F5>	
<F6>	
<F7>	Delete element
<F8>	
<F9>	Restart (i.e., reload screen)
<F10>	Return

3.10.11 Linker option module

This module provides the means for entering the various bottom-line boxes on the screen, and specifying the screen number which is linked to each of these boxes. Each of the eight types of bottom-line box has a fixed location along the lower edge of the screen the order from left to right being:–

Help, Map, Index, Back one, Re-start, Reading, Quiz, $\frac{Tour}{Next}$, *End session*

On entry to this module, the single-line information box reads:–

Set options <F1> for help

The help menu provides details of the function key commands, namely:–

<F1>	Help menu ON/OFF
<F2>	Provide help
<F3>	Provide map
<F4>	Provide previous
<F5>	Provide re-start
<F6>	Provide index
<F7>	Provide reading
<F8>	Provide exit
<F9>	Provide quiz
<F10>	Return

Default screen number codes (shown in brackets) were provided as the fixed screen links for *help* (901), *re-start* (1) and *exit* (999). For all options except *previous*, on pressing the appropriate function key, the information box reads, for example:–

Provide reading on screen 345 Enter new screen number, delete <F7> or accept <F9>

The default values are displayed and are not normally changed. For the *previous* bottom-line box, the information box reads:–

Provide previous delete <F7> or accept <F9>

The internal mechanism used to control the non-provision of a particular box is that its associated screen number code is zero.

3.10.12 Produce sounds module

The interface for including sounds into the screen files was the least developed of all the facilities as very little of use was made of sound output in the learning material. A fully-fledged graphical user interface would have required a considerable design effort. Eleven parameters are required to set each individual sound. In order to overcome this rather excessive input requirements, an option was provided to call predefined sounds from a sound library. On entry to this module, the on-screen help displayed the function key purposes, namely:–

<F1>	Help menu ON/OFF
<F2>	Preset sound
<F3>	New sound
<F4>	Set loudness
<F5>	Sound demonstration
<F6>	
<F7>	Delete sound
<F8>	
<F9>	More sounds
<F10>	Return

On selecting <F2>, the single-line information box displayed:–

Select single key to enter required sound

While the help box displayed a list of available sounds (e.g., A – triangle; B – high-drum). For the entry of a new sound (i.e., after entering <F3>), the information box presented the following series of questions:–

Attack time (0...1000ms)?
Final attack amplitude (0...15)?
Decay time (0...1000ms)?
Final decay amplitude (0...1000ms)?
Sustain time (0...1000ms)?
Final sustain amplitude (0...15)?
Release time (0...1000ms)?
Noise (0 = off: 1 = on)?
Tone (0 = off: 1 = on)?
Start pitch (0...388)?
End pitch (0...388)?

Figure 3.7 provides an explanation of some of these terms. All inputs were range checked, and after all parameters had been entered the sound would be produced.

Loudness was set (i.e., after entering <F4>) by using the cursor keys, as explained in the information box:–

Set loudness <— quieter —> louder <F10> to accept

3.10.13 Implementation details

The final version of **PED** consists of approximately 90 Kbytes of compiled code (this should be compared with 44.5 Kbytes for **LINKER**), and due to its size and highly modular structure was written as 15 source code program segments that were linked after compilation, together with five external procedure libraries.

3.11 Other Support Programs

Several other utility programs were produced to aid the creation and editing of screen files (and their associated text files) and tour files (i.e., binary files of screen code numbers for each tour). Of these, the most useful were a pair of programs that:–

- Converted a **SCREEN.$** file, and its associated **TEXT.$** file, into a single text file for editing.
- Converted text file (after editing) into the **SCREEN.$** and **TEXT.$** format.

The former was called **CONVERT** and the latter **REVERT**. In fact, the only means of including and editing **arith** elements in screen files was through using this pair of programs. **CONVERT** produced a text file of the format illustrated in Figure 3.36, which could be edited using a text editor. The resulting text file is named **CONVERT.$**, where **$** is the screen number.

The edited text file could be converted into the normal file pair using **REVERT**. All input was rigourously range checked If an error was detected in the textual description of an element (e.g., box) then the screen message '`Error in box`' was displayed. If the error was in the name of an element type then the screen message '`Incorrect element type - box`' was displayed. In both cases the following screen message was provided:–

```
Due to error in input file, screen files have not been created.
      The temporary files SCREEN.TMP and TEXT.TMP contain
      all valid elements prior to the error occurring.
```

```
circle
{x,y of centre} 200,150
{radius} 45
{centre colour} 3
{perimeter} 2
{width of outline} 1

fill
{x,y seed} 150, 45
{centre colour} 2

text
{contents} This is an example of some text
{size} 3
{colour} 3
{shadow} 0
{direction} 1
{font} 1

active
{lower x,y} 200, 34
{upper x,y} 260, 65
{screen} 34
```

Figure 3.36 Example of text file generated by **CONVERT**

If conversion was successful, then the following message was displayed:–

```
Screen files are SCREEN.56 and TEXT.56
```

After very little practice, this editing facility became a very fast and efficient means of manipulating files.

CHAPTER 4

PRELIMINARY USER TESTING

4.1 Introduction

Initial testing of the system had very broad aims as it was the first testing of both the hardware and software as well as exposure to users. As such this chapter is not only a chronological account of the early evaluation of the teaching package, but also it contains details of the modifications to the software made in light of exposure to users; and analysis tools developed. A number of possible areas for this evaluation are listed below.

4.1.1 Student requirements

It was envisaged that the system would be exploited for a variety of student tasks and activities. There would be, of course, general activities such as browsing the material in an informal manner and information searching; as well as more specific tasks such as revision and essay preparation. It would be interesting to know if the students themselves viewed the system as this flexible or, indeed, whether the system provided support for successful use across such a range of tasks. If would be particularly useful if we could identify the factors within the system that resulted in the students' perceived success.

4.1.2 Software and hardware evaluation

This evaluation represented the first serious testing of the computer network and software for multiple student use. Specifically it was a first testing of the Hitch-hiker's Guide after the initial prototyping cycles. Evaluation of the software involved two particular aspects.

The first was a testing of the main Hitch-hiker's Guide presentation software, and the second was a testing of the student *log-in program* and recording of log-file data.

4.1.3 Interface issues

These included students' use of the mouse as an input device and the overall structuring of the information screens. Of specific interest was the testing of the use of colour within the system and, more particularly, the application of colour for coding and highlighting functionality. For example, a design decision had been taken to identify particular screen types by using different colour combinations on the screen. For example, all information screens had grey backgrounds, whereas all maps had blue. Active or selectable areas were usually denoted by yellow text and on moving the mouse pointer into these regions, they were displayed in reverse video. The students' ability to use and understand the function of the various bottom line boxes and the various navigation methods were also under test. Did students elect to use these facilities, for example *tours*, *maps* and *indexes*, and was their use understood?

4.1.4 Use of the learning materials

Issues regarding the actual learning materials, were also of concern. Were the materials generally understood? Were some screens prone to frequent visits whilst others were missed, and if so what was the consequence of this? Issues on the amount and level of content per screen, and of the flow of information between screens, also needed investigating.

4.1.5 Methods of learning

Finally, methods of learning the system as well as the learning materials are worthy of study. Could teaching system usage really be left to the interface itself, with the minimum provision of on-line help facilities, or was expert intervention and tuition to prove necessary? Another aspect that seemed worth considering was whether use was made of 'local experts', namely other members of the group showing greater proficiency or confidence.

4.1.6 Chapter summary

The overriding aim of this initial work was to discover the salient features for further detailed evaluation, rather than to attempt total coverage of the points raised in the preceding paragraphs. The observational studies, design of questionnaires and the development of analysis tools for the user generated log-files were all motivated by this desire. Two studies are presented in which these factors were investigated. It should be remembered that the software and, more importantly, the content of the teaching package, were undergoing fairly continuous modifications. This makes the direct comparison of the two studies difficult. However, a number of valuable pointers for future work were uncovered and these are discussed at the end of this Chapter.

4.2 Study 1: Method

4.2.1 Subjects

The subjects were first-year students currently taking the cognitive psychology module of their undergraduate course. In the initial testing period, 22 of the possible 56 students took part in the evaluation.

4.2.2 Materials

The teaching material available on the system consisted of 60 information screens (40 on selective attention and 20 on short-term memory), 19 *help* screens, five *map* screens and one *index* screen. Twenty screens of reading lists/references were also included. Hence, the material was composed of a linked network of 105 frames. The screens were authored by the course lecturer and were specifically tailored to the course requirements.

4.2.3 Procedure

This preliminary investigation was carried out in naturalistic conditions. Subjects were invited to use the system as it covered material directly related to their coursework. Usage of the system was on a purely voluntary basis. Observations of the subjects' interactions with the system were made as unobtrusive as possible by the investigator sitting in the corner of the computer room and discreetly recording events and making notes. It was believed that the students perceived that the only purpose for the investigator's presence was for providing technical help.

Subjects were given no introduction to the system. Their questions were answered to solve the immediate query only but not to elaborate. The questions asked, remarks made and social interaction between subjects were all recorded. A questionnaire was given at the end of the session. System logging details were maintained for later analysis.

4.3 Study I: Results

4.3.1 Observational data

Surprisingly, little data was obtained by recording questions asked and comments made. In the first category, questions largely concerned the use of the mouse. The problems that novice users would encounter with the mouse had been underestimated (a few users attempted to use the mouse as a 'tracker' ball!), and it was necessary for very basic instructions to be given at the onset. This led to the modification of the first 'Welcome' screen to include more explanation of the procedure of moving the mouse and clicking to select items. The original screen is shown in Figure 4.1, and the modified screen in Figure 4.2. Obviously, the available help information gave more detailed explanations but it was necessary to master this machine-interaction method first in order to access the help facilities.

Social interaction was found to be minimal. Subjects did not work in groups; this may have been due to the voluntary nature of topic selection or possibly because the system presented no difficulties for the subjects to work individually. Comments made were generally regarding our choice of colours to denote functionality. These comments did lead to modifications. Other utterances were basically in reaction to certain screen changes, especially animation sequences and seemed to denote the surprise and novelty dimensions of the software.

The main sources of data were found to be the questionnaire and log-file data.

4.3.2 Questionnaire analysis

The questionnaire consisted of five questions which attempted to elicit information on why the student had used the system, how successful they had been in achieving this task and how easy they had found the system to use. They were also asked when they might use the system again, to highlight problems that they may have encountered and to offer suggestions for improvements. The questionnaire was kept short since students were asked to complete the same questionnaire at the end of all subsequent sessions. The questionnaire is given in Appendix A.

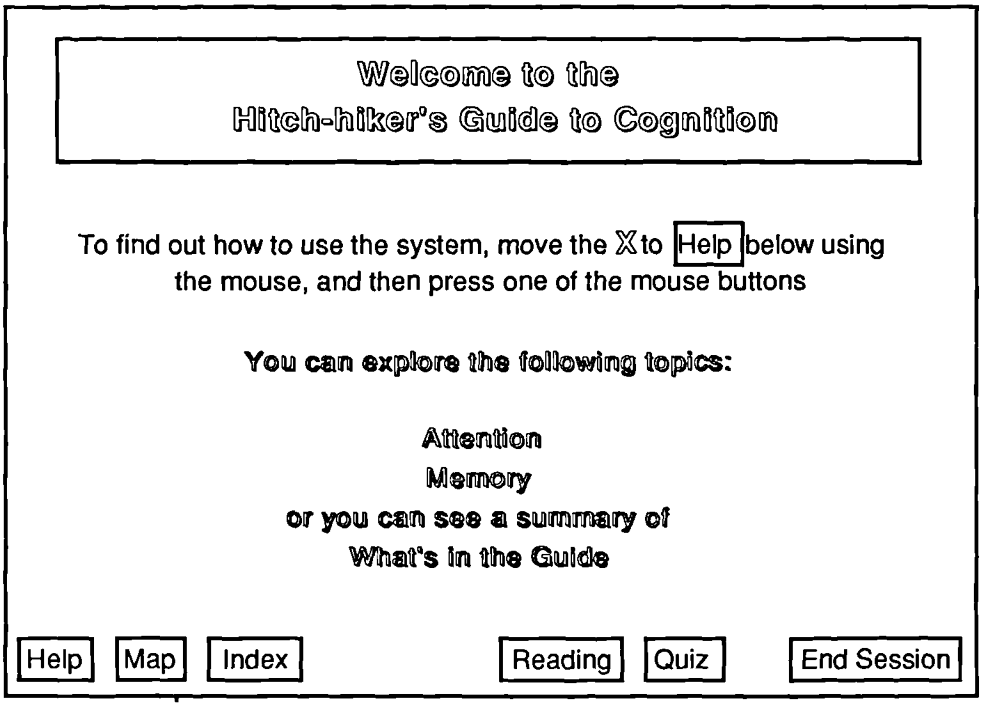


Figure 4.1 Original 'Welcome' screen
(Note: that the mouse pointer was a X at this time)

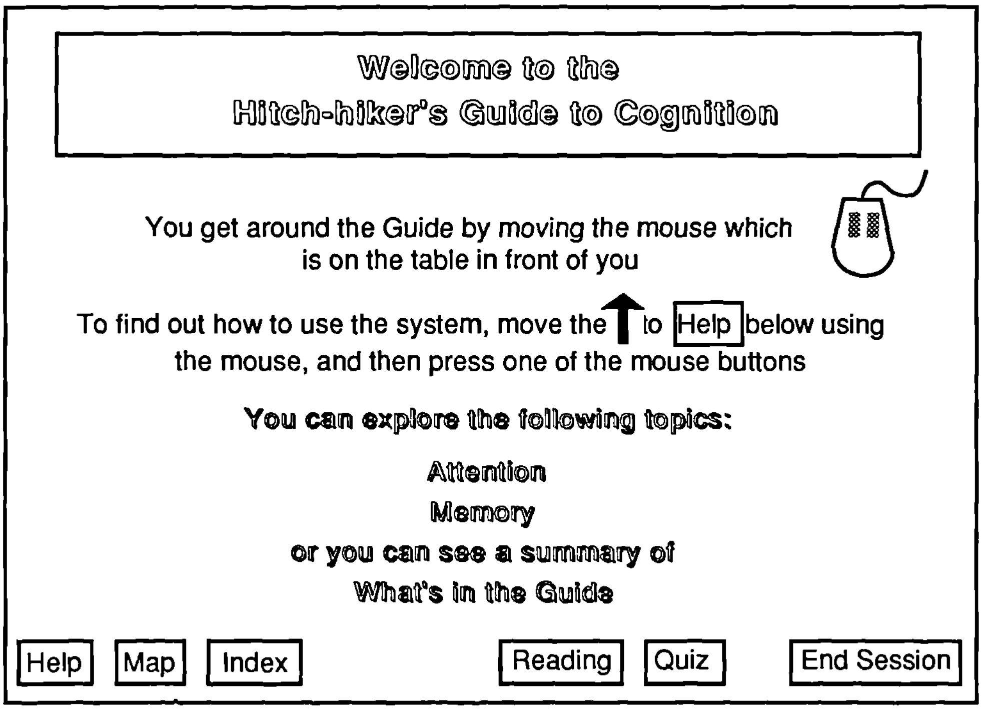


Figure 4.2 Modified 'Welcome' screen

Q1. Why did you use the system?

The responses to this question are given in Table 4.1. General browsing, finding specific information, essay preparation and supplementing lectures (after lectures) were found to account for 83% of responses. However, it must be said that these responses represent only a "snapshot" of student usage. A snapshot of usage prior to examinations may have put greater emphasis on the use of the system for revision.

Table 4.1 Response to Question 1 on perceived system usage

Q1. Why did you use the system?	%
General browsing	30
Finding out about a specific topic	18
Essay preparation	20
Specific reading list	9
Initial learning (before lectures)	0
Supplement to lectures (after lectures)	15
Revision	2
Others	4

One facility that proved to be very little used was the specific reading lists. This could have been because they had already been supplied with adequate paper documents from the conventional lecture course. Alternatively, as there was no printing facility available on the system, collecting these references, by writing them out, may have seemed tedious. In fact, although the provision of printing facilities was given, by a small number of students, as a suggestion for improvement of the overall system, this does not seem to be the case, as an analysis of the log data shows that subjects did not access these screens very often. Reading lists accounted for only 3% of the screens viewed although they were accessible from all of the information screens.

Q2. Were you successful in achieving what you set out to do?

A mean value of 57.4% ($\sigma = \pm 25.8$) on a continuous scale from 0% (completely unsuccessful) to 100% (very successful) was obtained. It is difficult to draw any conclusions from this figure, as we possess no comparative ratings for the students' *success* in using other information retrieval or learning systems. However, it is satisfying to see a reasonable spread of ratings approximately centred on the 60% figure.

Q3. How easy was the Hitch-hiker's Guide to use?

A mean value of 40.7% ($\sigma = \pm 33.0$) on a continuous scale from 0% (very difficult) to 100% (very easy) was obtained.

Q4. When might you use the system again?

Of the 22 students who used the system in this first instance, all of them reported that they would use the system again; twenty of them reported that they would use it within the following two weeks. Their intent to use the system further was encouraging, but in fact only ten students returned. This was possibly because the material covered such a small area of the psychology course and that the time-slot for this particular topic had passed. The students who did return, spent an average of 64 extra minutes using the system. Average time for the initial session (all 22 students) was 36.4 minutes.

Q5. Any other comments?

Comments were generally favourable; the system was seen as "fun" and "a useful addition." Problems encountered reflected the verbal comments reported earlier in that a few users experienced difficulties in controlling the mouse (four subjects) and there were some comments regarding what was seen to be an inappropriate use of colour. This, as has been noted, prompted some changes to the system. It should also be noted that colour was seen to be generally a positive feature.

Correlation analysis of the subject's responses to the questions on success and ease of use, show a significant correlation ($r = 0.517$, $p \leq 0.01$). If subjects rated themselves successful in achieving their tasks, they rated the system as easy to use. Although in some ways this may seem intuitive, it is not obvious that this correlation should exist. A student may have some unrealistic goal, for example to search for some material not present in the system. Failure in this would result in a completely unsuccessful use of the system, but would not at all reflect its ease of use. However in the early stages of system usage, it would seem that successful outcomes and the students' opinions on the ease of use of the system are related. When a further analysis was made on the 12 subjects who had used the system for more than thirty minutes on their first session, the correlation between ease of use and success was not found ($r = -0.226$, $p = 0.24$). This may indicate that with more extended usage, subjects are able to differentiate between these two concepts.

4.3.3 Log-file analysis

The log-files collected generated a vast amount of data. This data can be analysed in one of two general ways:–

- Extraction of global measures, such as time spent on the system, number of screens visited, number of help screens visited, time spent per screen.

- Extraction of specific patterns, or sequences, of use to address particular issues. For example, "Given a number of possible active links on a screen, which option is usually preferred?" or "Do subjects use the navigation facilities provided in a particular way, for example, are tours usually completed once started or do subjects generally divert from tours?"

4.3.4 Extraction of global features

The log-files of the 12 subjects who used the system for more than 30 minutes on their first usage were used for analysis. Less than 30 minutes could have resulted in distorted measures of facility usage as the subjects may not have had time to explore all of the system's functionality. A log-file analysis program, called **`logstat`**, was written that analysed the raw log text files to produce values for the active time per screen, running total time and a range of global measures. A typical print-out is given in Figure 4.3.

Navigation from screen to screen can be categorised broadly into three areas:–

- Hypertext links – screens are accessed by clicking on active areas within the text/graphics screen.
- Bottom-line boxes, these consist of *help*, *restart*, *back-one*, *reading*, *map* and *index*.
- Tour facility. (Tours once initiated are maintained, however, by the selection of a bottom-line-box, but for the purpose of this analysis are kept separate).

```
RESULTS FOR LOG.40
*
N      1    4964    0.49
N      4    5124    1.40
N      8    5834    2.69
N     11    3994    3.18
N      8    2858    4.53
P     11    2138    4.82
|      |       |      |
|      |       |      |
N     47    3762   69.34
S      0   25714   73.98
E    400      54   77.05
F

Consolidated Results for this Logfile --->

Total Active Time  = 57.29 min
Total Dead Time    = 15.56 min
Total Time         = 73.26 min

Total Sessions  =  1

Mode     Number    % of Total  Average Time (s)
  B        19       12.67        11.88
  H         0        0.0             ?
  M         8        5.33        24.44
  I         1        0.67        31.44
  S         2        1.33       139.19
  R         0        0.0             ?
  N        34       22.67        37.12
  T        78       52.0         27.10
 B-L-B     30       20.0         24.36

Total Screens Seen    = 172
Total Novel Screens   = 45   26.16 as % of total screens seen
                      88.24 as % of total possible screens (51)
Total Info Screens    = 111  64.53 as % of total screens seen
Seen
Total Novel Info      = 37   33.33 as % of total info screens seen
Screens
                      90.24 as % of total possible info screens (41)
```

Figure 4.3 Sample consolidated log-file
(See following page for notation)

Log-file Notation

Line 1 — Header that identifies the subject via the file extension number

Line 2 — Symbol(*) to mark start of session

Lines 3-13 — Individual screen details – per line:–

<User action>

<Screen number>

<Active time per screen, in $\frac{1}{100}$ seconds>

<Consolidated total system time, in minutes>

<User action>	N	next screen, ie conventional hypertext link
	P	previous screen, ie *back one* facility
	H	activation of help facility
	M	activation of map facility
	I	activation of index facility
	R	activation of reading facility
	Q	activation of quiz facility
	T	activation of tour facility, and its continuation
	S	activation of re-start facility
	E	activation of end session facility

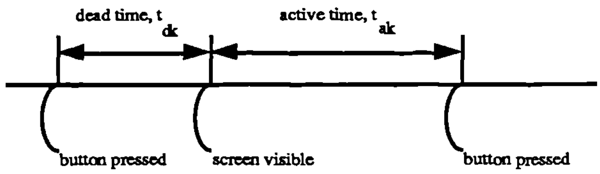
<Screen number>	unique number of screen displayed
<Active time per screen>	time interval between screen being displayed and next button press
<Total system time>	running total of time on system

Line 14 — Symbol(F) for end of session

The remainder of the output file contains various global measures.

Line 18 — Total active system time = $\sum_{k=1}^{N} t_{ak}$

Line 19 — Total dead system time = $\sum_{k=1}^{N} t_{dk}$



Line 20 — Total system time = $\sum_{k=1}^{N} (t_{ak}+t_{dk})$ (Slight differences in total timing are due to rounding errors)

Line 22 — Total number of sessions

Lines 24-33 — Breakdown of user interaction

Mode	Interaction type – codes as above, with addition of B (double button presses – highlight selectable areas) and B-L-B (all bottom line boxes, ie {B,H,M,I,S,R}).
Number	Number of interactions of this type
% of Total	Percentage of total number of screens seen
Average time	Average active time per screen in seconds

Line 35 — Total number of screens seen, including all repeats

Lines 36-37 — Total number of unique screens seen, ie no repeats counted expressed as percentage of total screens seen and as percentage of possible screens – this number is displayed in brackets at end of line

Line 38 — Total number of information screens seen, including repeats

Lines 39-40 — Total number of unique information screens seen, ie no repeats counted expressed as percentage of total information screens seen and as percentage of possible information screens - this number is displayed in brackets at end of line.

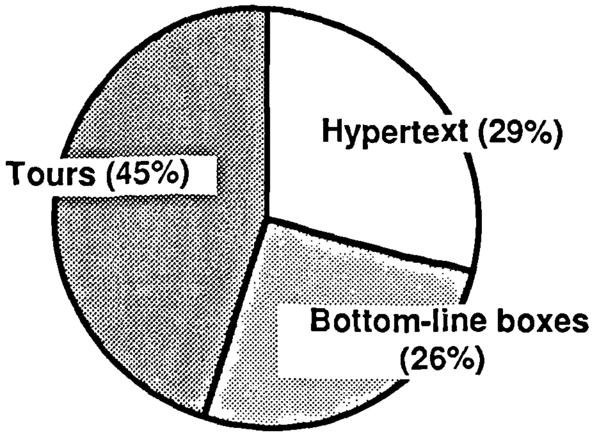


Figure 4.5 Use of navigational links in Study I

The recorded percentage use of these three categories is illustrated in Figure 4.5. Our initial concern that subjects would choose, in preference, only one access method during the early stages of system interaction was unfounded. It could be suggested that tours are the favoured navigation method for novice users. The exact nature of the hypertext structures employed in this study would need to be examined before being able to make this claim. Naturally, the availability of tours is important. For the material considered here, students were advised to use the tour facility to access the help information. This may have made a substantial contribution to total tour usage.

Eighty-three percent of the subjects used three or more of the navigation methods – hypertext, tours, index and maps. This indicates that novice users made extensive use of the navigation facilities that the Hitch-hiker's Guide provides over and above the normal hypertext links. This suggests that these interface features are easy to use. A closer analysis of the bottom-line-boxes accessed, shows that the majority of the subjects (67%) explored all the facilities within this first session. The balance between the use of hypertext links (on screen) and bottom line boxes (a special class of hypertext link) may reflect the structure of the material. Much of the material presented (especially the divided attention module) was presented in a linear (i.e., chronological) manner, permitting few opportunities for branching. Issues of authoring and content are beyond the scope of this thesis but it has been observed that the structure of hypertext is very much dependent upon the structure of the material that it embodies. This will naturally be reflected in the pattern of navigation facilities employed.

Pearson correlation tests were carried out on data collected from the log-files to highlight any salient relationships that might exist between variables. The following significant correlations (see Table 4.2) were found – some, of course, rather obvious ones!

Table 4.2 Correlation matrix for log data from Study I

	Hyper-text	Index	Map	Tours	Total screens	Total info. screens	Novel info. screens	Time per screen
Hypertext	-	0.281 ns	0.516 p=.043	-0.944 p<.001	-0.597 p=.020	0.037 ns	0.138 ns	-0.455 ns
Index		-	0.276 ns	0.243 ns	0.591 p=.022	0.540 p=.035	0.083 ns	-0.706 p=.005
Map			-	-0.595 p=.021	0.336 ns	-0.344 ns	0.655 p=.010	-0.471 ns
Tours				-	0.625 p=.015	0.203 ns	-0.181 ns	0.502 p=.048
Total screens					-	0.730 p=.004	-0.053 ns	-0.629 p=.014
Total info. screens						-	-0.288 ns	0.428 ns
Novel info. screens							-	-0.269 ns

Note: ns – not significant correlation (p > 0.05).

There was a positive correlation between use of map and the number of novel information screens seen – this suggests that users were using the maps to ensure a more complete coverage of the material (through use of the *footprinting* facility). Negative correlations such as that between use of map and use of tour may suggest that users fell into two groups. Those who used *go-it-alone* travel (map users) and those who felt the need for more system control (tour users). Further evidence for these two types of user is provided by the positive correlation between use of hypertext and map, and the negative correlation between use of hypertext and tours. The other navigational technique for the *go-it-alone* traveller – the index – showed a positive correlation with both total number of screens seen and total number of information screens seen. There was, also, a negative correlation between use of index and the viewing time per screen. This could imply that navigation about the information base using the index may not be an efficient mode of navigation – but we cannot answer the question as to whether this inefficiency lay with the learning style of the user or with an index as a method of information access. Users who predominately employed hypertext navigation tended to view fewer screens, whilst those who used tours tended to see more screens.

There was a negative correlation between the number of screens seen and the time spent on each screen. There may be a trade-off here, subjects using the hypertext navigation may be studying the material more closely. In order to make this claim, the log data would need to be studied in further detail to isolate times spent on individual information screens. However, further speculation cannot be made from study of the log data alone. It is important to know something about the real intention of the subject. Did the student choose this form of navigation to promote learning, or is learning promoted by this form of navigation? An alternate explanation for this data may simply be that using hypertext links give more freedom of choice to the students, and the extra time per screen merely reflects the necessary decision time. Card, Moran, and Newell (1983) postulated that the more choices available, the longer the expected response time. Recent work by Olson & Nilsen (1988) has offered some experimental evidence to support this hypothesis.

The *back-one* facility proved to be useful in that it accounted for an average of 10% of all system interaction. It thus seems to play a major role in navigation although the actual extent of usage varied widely within the group. Subject S6, for example, used this for 33% of their interactions, at the expense of using either the map or index. This subject also failed to use the help facility, and so may not have understood the functionality, or may have wished to keep their interaction very simple.

The *restart* facility was used on average for 3% of all interaction. This would seem a reasonable rate of use. It is obviously a useful provision but over-use of this facility could have reflected the subjects' lack of orientation within the information frames.

4.3.5 Patterns of usage

The global statistics give some indication of how the system is used but very little idea of why. Studying patterns of screen access may be more useful here. The sorts of strategies students adopt, coupled with their reported usage, may give us more information as to their success either with the system or with the educational objectives. Using all the facilities available is of little use if they do not provide support for the students in their educational goals. Within the current experiment, the following issues were investigated:–

- Use of the help facility
- Use of the tour facility.

4.3.6 The help facility

Not all subjects chose to use the available help facilities although instructed to do so by the Welcome Screen. Help was also accessible from all the screens via a bottom-line *help* box. The two subjects, who failed to use help, S6 and S9, did in fact use fewer of the available facilities. S6 did not use the *back-one*, the *index* or the *restart* facility. S9 did not use the *back-one*, *index* or *tour* facility. Analysis of the actual log-files shows that some of the help screens were seen by most of the subjects (83%), whilst other areas of the help information were only accessed by a small number of the users. Analysis revealed that the tour within the help information describing the 'Why?' ('What it's all about?') of the system was explored first (see Figure 4.6), but that after this the subjects often chose to return to the information system (sixteen completed the first tour, only eight started on the second) rather than embark on a further tour ('How to get around') of the help information, even though this would have permitted the acquisition of the more useful procedural knowledge on help (see Figure 4.7, the first screen of the 'How to get about' tour). Feedback from this early study led to an improved implementation of the help materials, that have proved more successful in later testing (the later implementation is shown in Figures 4.8 and 4.9). "More successful" here means that a larger proportion of the subjects saw all of the available help screens. The total number of screens was reduced from 19 to 11 (the tour 'What it's all about?' was reduced to only two screens) and more direct access to assistance on key facilities was supplied as shown in Figure 4.9 (a list of active areas providing access to single or in some cases two screens of help).

4.3.7 The tour facility

The analysis of the global data show that the tour facility was used to a considerable extent. It does not, however, indicate if the tours were used appropriately. In this version of the Hitch-hiker's Guide, tour status was indicated by a label on the top corner of the screen, and the presence of a *next* box on the bottom line. Later versions of the software replaced the label with a sprite icon of a bus. As this icon replaced the usual arrow icon while a tour was selected, students attention was more closely focused to the tour status.

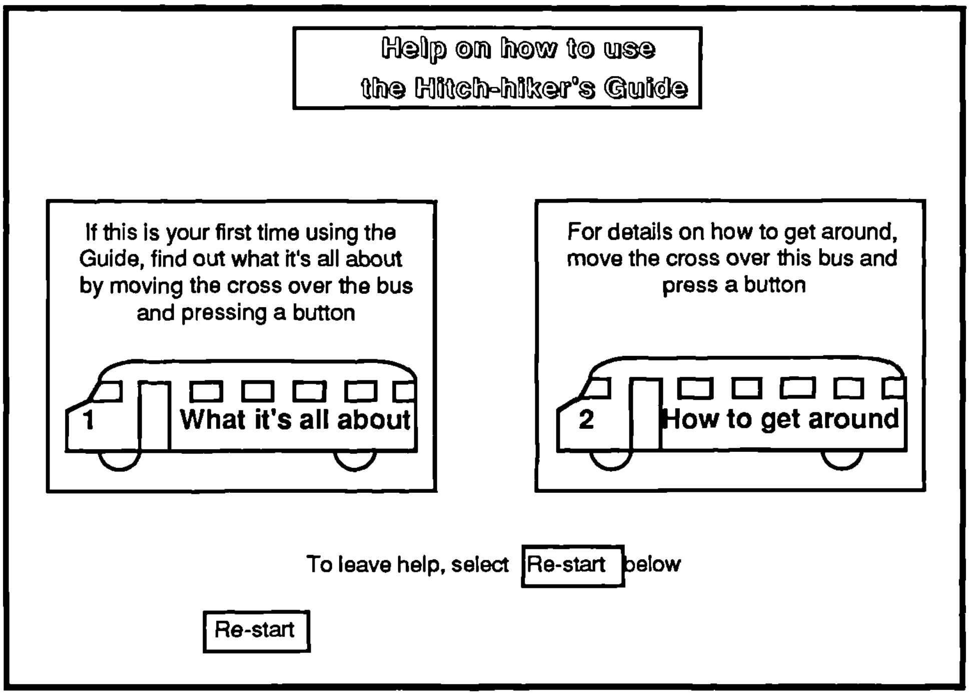


Figure 4.6 Original first help screen

The navigating functionality of tours may not be immediately apparent to users, for example did the subjects realise that they could leave a tour at any time and that they could rejoin it at any later time? From the log data, sequences of screens representing tours or parts of tours can be isolated. For example, from the 22 log-files studied, 16 of them were found to have completed the help tour 'What it's all about'. The second help tour (which contained the procedural information) was only completed by four students, though a further four had embarked on this tour. We can see that subjects do leave tours. This second tour was 11 screens long. The length of the tour may be important here as similar features were observed for the tours within the information screens. Short tours tended to be completed, whilst longer tours did not. Instances of students rejoining tours do exist in the log data, particularly where the divergence is just to view one screen, for example a reading or a map screen. However, these instances would seem to be rare.

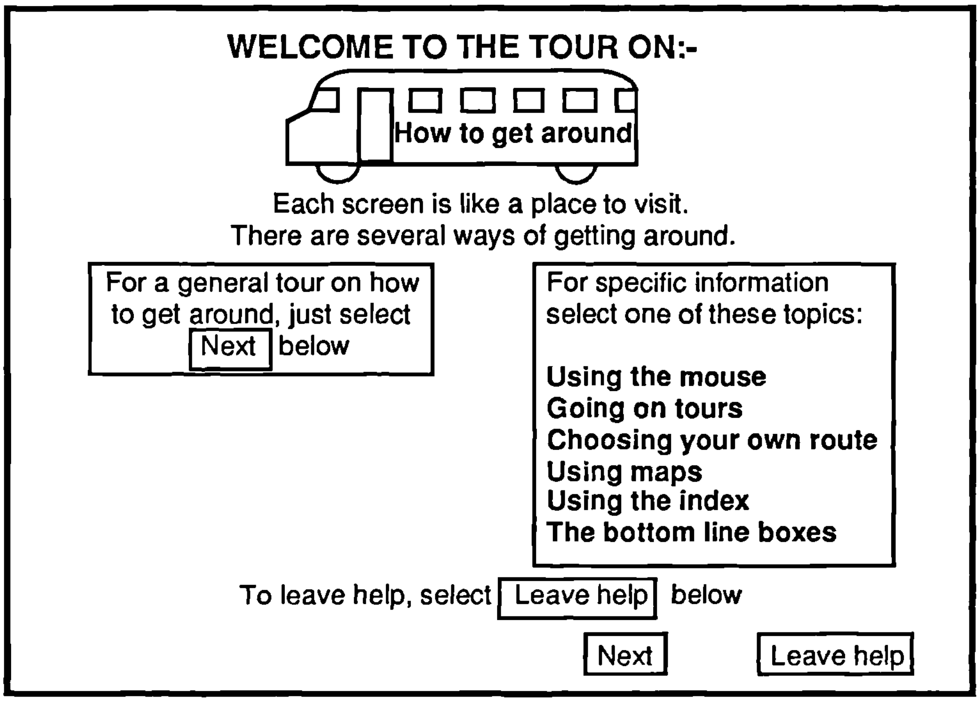


Figure 4.7 Original second help screen

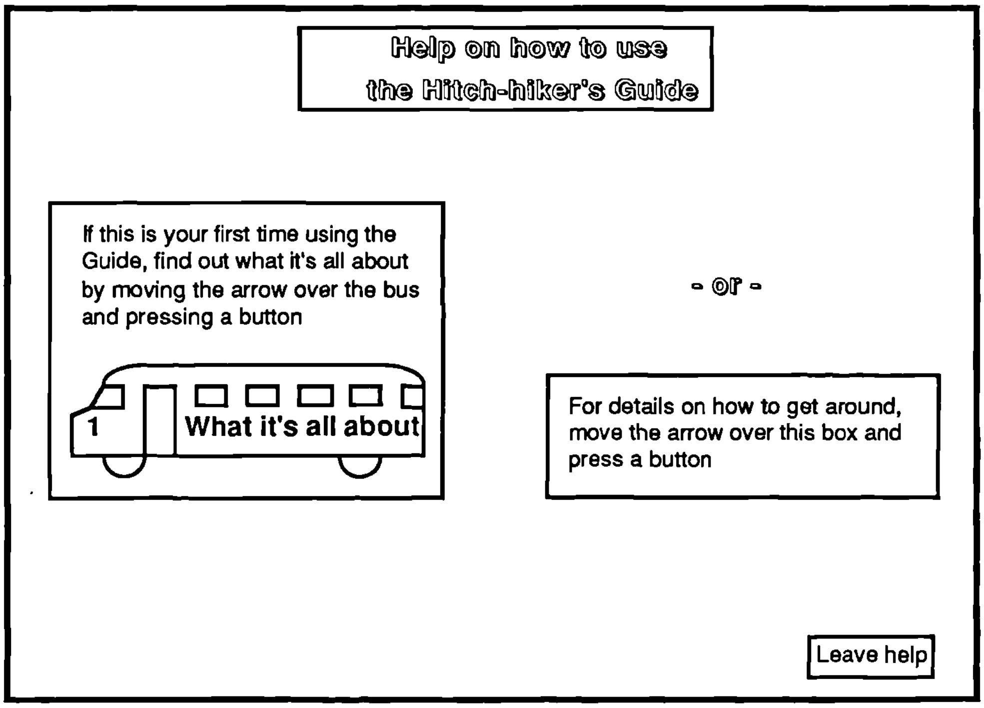


Figure 4.8 Modified first help screen

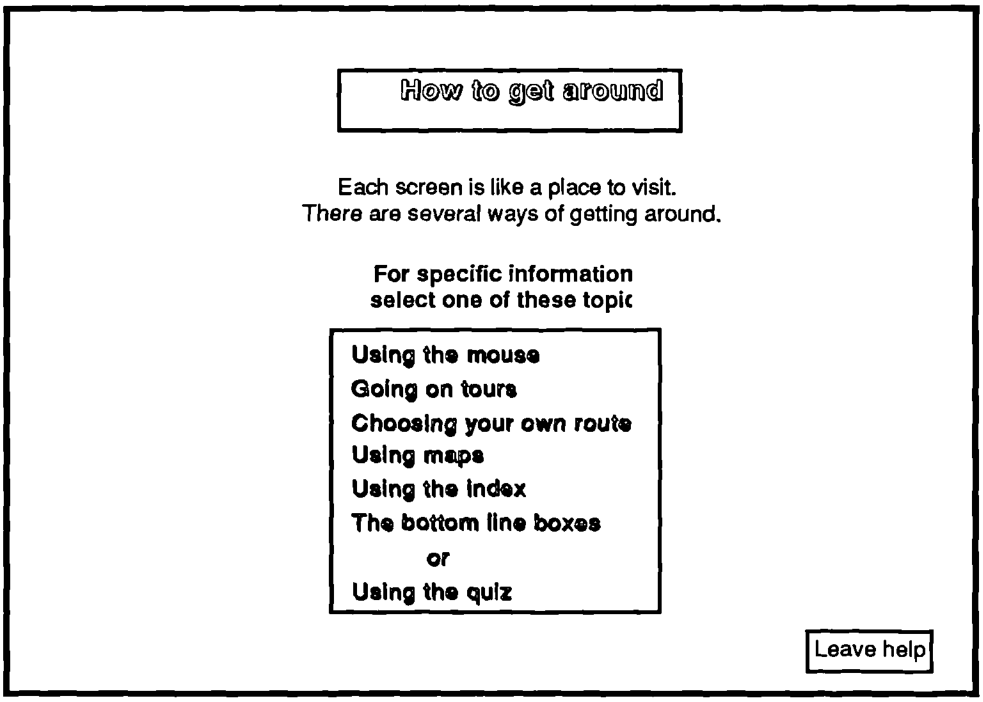


Figure 4.9 Modified second help screen

4.3.8 Conclusions

Our goals at the onset of this initial evaluation were broad and wide-ranging. The results obtained cannot be expected to satisfy all our categories of evaluation, especially as the system was far from complete. This last fact affected the range of issues and facilities that could be investigated. Certain issues appear to have been addressed more satisfactorily than others.

We were able to isolate the sort of applications for which this group of students used the system. This is only a *snapshot*, later sessions or indeed later groups of subjects may reveal different patterns of activity. There is also a problem of defining the students' tasks. It is not at all clear what a student should perceive browsing to be, and in what way it is different from information searching. This confounds our classification problems with student uncertainty.

Analysis of navigation (tours, hypertext, maps, indexes) indicate that multiple methods were used by most students. For example, only one subject from the group of 12 failed to use tours. All subjects used hypertext and the bottom line boxes in some way. A majority of subjects used both the map and the index facility; eighty-three percent using at least one or other of these. This would suggest that the navigation methods were both easy to understand and easy to use. Evidence to assess whether these facilities were used in a way appropriate for the tasks and goals of the student, however, would require further investigation.

The evaluation failed to consider the information content of the screens other than to highlight problems that may occur in accessing particular screens. For example, log-files were analysed for the number of times a particular screen was visited. This identified a crucial screen of information in the *Attention module* that had, in fact, been missed by the majority of users. A modification in the network structure remedied this situation.

4.3.9 Practical considerations

The first exposure of the system to real use was encouraging. The software proved to be robust and data collection was effective. These were encouraging as this was the first testing of a networked version. It was also an opportunity to measure system response times. Selection of an active area with the mouse resulted in immediate clearing of the screen, this was followed by file-access time and screen drawing time. It had been a design decision to sequence events in this way, file access could have occurred prior to clearing the screen but it was believed that the user needed immediate feedback on mouse activation. In this particular evaluation, speed of screen presentation was not found to be a problem.

Later testing using a larger information network did produce problems in this area. Disc access became a problem when the number of files within a directory became large (i.e., large number of screens). This problem was in the first instance addressed by software changes to allow swapping of files to RAM memory in the user workstation prior to access. The current solution is the use of a faster network server with better disk access times. Details of the software solutions to these problems are given in Chapter 3.

Our evaluation of the interface highlighted the problems of mouse usage encountered by some novices and the unacceptable use of colour in certain screens (the intended colour coding for different types of screens resulted in one objectionable colour combination). These are broadly ergonomic issues. More HCI-based issues relate to the actual use of the facilities, the bottom line boxes, and whether maps and indexes were both selected and selected from. Our evaluation does suggest that these facilities were used, and used appropriately.

4.4 Study II: Method

4.4.1 Introduction

Continued development of the teaching package, in particular the inclusion of further information modules and a self-assessed quiz facility, meant a further study was warranted. Essentially the same methodology as in Study I was employed with slight changes resulting from the experience gained in that study.

4.4.2 Subjects

The subjects this time were second-year students, again taking the cognitive psychology undergraduate course. Due to a restructuring of the degree course at this time, it was possible to complete this study in the term following Study I. Course requirements for this particular year were identical to the requirements of first year students in Study I. During the course of the term, however, students had to prepare for a tutorial on topics covered in the information on the system. Twenty-five students took part in this study.

4.4.3 Materials

Available information on the Guide had by this time increased. The information screens now included 42 screens on sensory memory, associated reading screens and two additional map screens.

Multiple-choice quizzes were also provided. Quizzes for each information module generally consisted of ten question screens, each associated with their response screens (one correct and three incorrect answers). Each quiz module, therefore, consisted of about 50 screens. The total information system consisted of 165 screens, plus quiz screens. There were two quiz modules. Examples of quiz question and answer screens are given in Figure 2.7(a – c).

4.4.4 Procedure

As in the previous study, students used the system on a voluntary basis. This time, no observational study was attempted. Questionnaire and log-file data were collected as previously.

4.5 Study II: Results

4.5.1 Questionnaire analysis

Twenty-five students used the system - that is, 53% of the year group, compared with 39% in Study I. Twenty of these students used the system for more than 30 minutes. The questionnaire and log-files of these 20 students were analysed. In the second study, questionnaire data from all sessions were combined (students completed questionnaires after each visit). This section will not only report the findings from the Study II questionnaire but also relate them to those of the first study.

Q1. Why did you use the system?
A similar pattern of reported usage of the system occurred as in the first study, where 83% of usage was identified by the users as being browsing, essay preparation, information search or supplementing lectures. In this study, 93% of the usage can be explained by browsing, information searching, revision and supplementing lectures. In this study the system was not used as extensively for essay preparation but information search and revision tasks take on more prominent roles. This may reflect the different tasks required by the students as the first year students were required to produce essays for the tutorials on the course, but the second year students were required to produces short notes on a number of topics.

The first study represented a *snapshot* of system usage as only the first session's questionnaires were analysed. The results presented in Table 4.3 show averaged perceived system usage over all sessions (average of 3.1 sessions per Study II subject). The reasons for using the system were seen to change over sessions, possibly reflecting the changing course requirements over time.

For the second and third questions, relating to the success of the perceived goals as given in Q1 and the ease of use, only first session questionnaire data were analysed. This gives a direct comparison with the first study.

Table 4.3 Response to Question 1 on perceived system usage

Q1. Why did you use the system?	Study I %	Study II %
General browsing	30	35
Finding out about a specific topic	18	30
Essay preparation	20	3
Specific reading list	9	1
Initial learning (before lectures)	0	3
Supplement to lectures (after lectures)	15	11
Revision	2	17
Others	4	0

Table 4.4 Responses to Questions 2 and 3

	Q2 – Success		Q3 – Ease of Use	
	Mean(%)	σ	Mean(%)	σ
Study I	57.4	±25.8	40.7	±33.0
Study II	94.5	±7.0	84.9	±14.2

Q2. Were you successful in achieving what you set out to do?

The mean rating for the Study I group is lower (i.e., less successful) than that for the Study II group (see Table 4.4). This indicates that the Study II group interaction resulted in more successful usage. This difference is significant at the $p < 0.001$ (two-tailed) level using a Mann-Whitney U test ($U = 14.0$; mean ranks 24.7, 10.7).

Q3. How easy was the Hitch-hiker's Guide to use?

The mean rating for the Study I group is again lower than the mean rating for the Study II group (see Table 4.4). This indicates that, in Study II, the system was rated as easier to use. This difference is significant at the $p < 0.001$ level (two-tailed) using a Mann-Whitney U test ($U = 21.0$; mean ranks 23.8, 11.1).

It is difficult to pin-point why these improvements occurred as a number of factors could be involved. The information content of the system had been expanded dramatically during the time between these two studies. Second year students should be more experienced in study techniques (they were in their fifth university term, while year one students were in their first). Differences could, indeed, be due to the fact that second year students possess more experience of computers – finding them easier to use and hence more successful in their interactions. This does not seem to be the case as no correlation was found in Study II between ease of use and success ratings. Students seem to be able to differentiate between these two questions, since in Study II a significant difference was found between ratings for ease of use and success. This difference is significant at the $p < .05$ level using a two-tailed within-subjects t-test ($t = 2.76$, $df = 18$, $p = 0.013$). This suggests that students are more positive about the success of their interactions than the ease of use of the system. This is encouraging as success or usefulness would surely be a more likely predictor of future system use than ease of use. Seventeen out of 20 (85%) of subjects in this study returned to use the system. Average time using the system was also increased for this group. Average time for first session was 47 minutes for this group, and the average total time was 101 minutes.

Other possibilities for these changes in user views relate to the developing nature of system itself. The information network had increased to include further topics (more information) and further facilities (quizzes). This could well be reflected in the success ratings, since students found more use for the system as regards the course syllabus and more potential forms of usage (quizzes can be used for self-testing purposes and also as determinants of learning strategies). Some students used quizzes to highlight the areas for further study. A further analysis of the use of quizzes is detailed later.

Finally, as mentioned earlier, feedback from Study I led to changes in the system, although none of these changes in themselves were major, they could have contributed to the overall system evaluation. As the evaluation was in no way intended to represent a scientific study, continuous development of, and improvement to, the system can be justified. We were employing a system prototyping technique.

It is evident from this questionnaire analysis that the students are using the system for a variety of purposes as intended. Also, that during development, the system appears to be becoming increasingly easy to use by the novice user who is also experiencing increasing success. As well as looking at the changes that are occurring on these scales from Study I to Study II, it is interesting to note the detailed results. In Table 4.4, ease of use is measured on a scale from 0 to 100, where 0 represents 'very hard' and 100 'very easy'. Success is measured on a scale from 0 to 100 where '0' is 'completely unsuccessful' and '100' is 'very successful'. Ratings for ease of use and success are very high for the second study. Study II subjects rated it very easy to use and also rated their system usage as very successful. The responses represent very good ratings of the system which probably allows little or no room for improvements.

4.5.2 Log-file analysis

Correlation analysis of the log data collected failed to replicate some of the earlier findings of Study I. Table 4.5 details the correlations found for Study II. Of the 12 correlations found for Study I and six for Study II, only three remained unchanged. For example, in Study I, use of hypertext navigation was found to be negatively correlated with total screens seen. This was not replicated in this second study. The existance of groups of users who employed *go-it-alone* travel or employed more guided navigation is not so clear. Map and index use were postively correlated. Failure to reproduce the earlier results could have been due to the changed nature of the system since Study I. The introduction of quizzes changed patterns of system usage. Twenty-two percent of all screens viewed were quiz screens, and a navigation through quiz screens was a mixture of bottom-line box selection (quiz box to access both the quiz and a new question) and hypertext navigation (to select answer).

The inclusion of this hypertext navigation into the total hypertext data may have distorted the analysis. This is borne out by the results shown in Table 4.6, where the bottom-line boxes (this time including quiz boxes) were used more by the Study II subjects. The means represent the average percentage of the total navigation that resulted from the use of bottom-line boxes (*help, back-one, re-start, reading, index, map, end session*). This difference is significant at the $p < 0.01$ level (two-tailed) using a Mann-Whitney U test ($U = 48.5$; mean ranks 10.5, 20.1).

Table 4.5 Correlation matrix for log data from Study II

	Hyper-text	Index	Map	Tours	Total screens	Total info screens	Novel info screens	Time per screen
Hypertext	-	0.122 ns	0.366 ns	-0.770 p<0.001	-0.095 ns	-0.172 ns	0.335 ns	-0.159 ns
Index		-	0.412 p=0.035	-0.130 ns	-0.196 ns	-0.188 ns	0.108 ns	0.039 ns
Map			-	-0.201 ns	0.068 ns	0.188 ns	-0.099 ns	0.164 ns
Tours				-	0.065 ns	-0.159 ns	-0.231 ns	0.227 ns
Total screens					-	0.882 p<0.001	0.566 p=.005	-0.122 ns
Total info screens						-	-0.712 p=0.000	0.116 ns
Novel info screens							-	-0.203 ns

Note: *This is an identical format to the correlation table for Study I (see Table 4.2). Correlations that have changed from significant to non-significant, or vice versa, from those of Study I are indicated by underscores.*

Table 4.6 Percentage use of facilities in Study I and Study II

	Study I		Study II	
	Mean(%)	σ	Mean(%)	σ
b-l-b	26.5	±7.5	35.6	±7.8
index	3.1	±3.3	7.4	±5.1
map	5.6	±9.0	2.3	±2.9
tours	44.7	±20.8	30.6	±10.3
hypertext	28.8	±16.4	34.3	±6.7

For Study II, the *Quiz* box was selected an average of 14.7% of total mouse actions. (This includes selections from within the quiz itself; that is each time a question is accessed.) Quiz screens also distort the total screen figure. Navigation through these screens can be very rapid, time spent on 'feedback screens' either 'correct' or 'incorrect' is much less than on question screens or information screens. Hence the global statistics, for time screens were viewed, have been distorted. We did not replicate the result found in Study I that a negative correlation exists between number of screens and time spent on screens.

There was, however, significantly more use of the index facility in Study II. The differences of means in Table 4.6 is significant at the $p < 0.01$ level (two tailed) using a Mann-Whitney U test ($U = 52.5$; mean ranks 10.9, 19.9).

Again, there was a positive correlation ($r = 0.412$, $p = 0.035$) between the use of maps and index (see Table 4.6), showing that subjects did not use one method to the exclusion of the others. But, in Study II, the index was the preferred facility. This difference is significant at the $p = 0.001$ level using a two-tailed within subjects t-test ($t = -4.89$, $df = 18$).

The increased use of index in the second study is likely to be a result of the differing goals of the students. These students had specific topics to study for a tutorial, and hence their usage was more likely to be directed to these goals. An index facility assists in providing a direct access to these topics. In this case, browsing is inefficient and using a map, which gives information of related topics as well as material not yet viewed, may seem unnecessary. In fact, we would had predicted this form of navigation to best suit information search. What is more surprising, however, is the very low usage of maps. Maps were used more in Study I, but this difference was not significant.

4.5.3 Individual differences

From a closer analysis of the log data it can be seen that clearly different strategies are employed by users. This is evident in the wide variation of percentage use of many of the facilities. For example, in Study II, there is an example of a student who relied heavily on the use of the *back-one* facility – 19% of all their system interactions. It is impossible, from log data alone, to say that these differences reflect users' tasks and goals or whether they occur through differing cognitive styles.

From studying the log-files we can make some inferences of the sort of learning that the students were endeavouring. Some were attempting careful navigation though the screens, taking time to consider the material carefully and paths appropriately. Many of these students were observed to be actively engaged in note-taking activities. While another type of students can be observed from the log-file record and their interaction at the terminal to be merely flitting through the screens – at a rate too fast for close study but possibly with a view to gaining an overview of either the system itself or the embedded material. Again, is this characteristic of the students themselves or of their current goal?

Careful analysis of the use of the quiz facilities was more illuminating. We can isolate different approaches to the use of this facility. For some, it is used early in the system interaction prior to study of the information. In this case, it is used as a self-testing facility or an advance organiser for further study. It was, also, used after the study of the materials for self-test or revision. Some log-files show a systematic use of this facility.

4.6 Longitudinal analysis of log-file data from Study II

It was the general observation of changing system usage with exposure, as noted in the previous section, that prompted an investigation into the users' activity as a function of time on the system. Software analysis tools were developed that permitted the histogramming of user's action either as a function of specified time intervals or specified number of screens seen. The purpose of these tools were to investigate the changing use of the system's functions over time and to explore if characteristic individual styles of use existed.

4.6.1 Method

The analysis program **`logstat`** was extended to include the histogramming of screens, by their general type, as a function of a specified number of screens seen or active time slots. Typical output result file for time intervals of five minutes is shown in

```
RESULTS FOR LOG.18
Interval = 5.0 mins
 E    H    I    M    N    P    Q    R    S    T   Total   Time
 0    0    0    0   11    1    0    0    2    0    14      5.0
 0    0    0    1    9    1    0    0    2    0    13     10.22
 0    0    0    2   10    3    0    0    0    0    15     15.31
 1    0    0    2    8    5    0    0    1    0    17     <--
                                                         Residual
```

Figure 4.10 Specimen output of a **`slot.$`** *file*
(The column letters refer to screen type)

Figure 4.10. These output files are named as **`slot.$`**, where **`$`** is the individual user's identification number. Though the binning by number of screens is accurate, a comment on time-interval binning is necessary. Since the user's timing of screen changes is not

synchronous with the specified time slots, then the algorithm illustrated in Figure 4.11 was adopted. The errors introduced are not significant for the time intervals employed in the subsequent analysis. Note that the timing is based on the active screen time – the interval between screen fully present and the user's next button press.

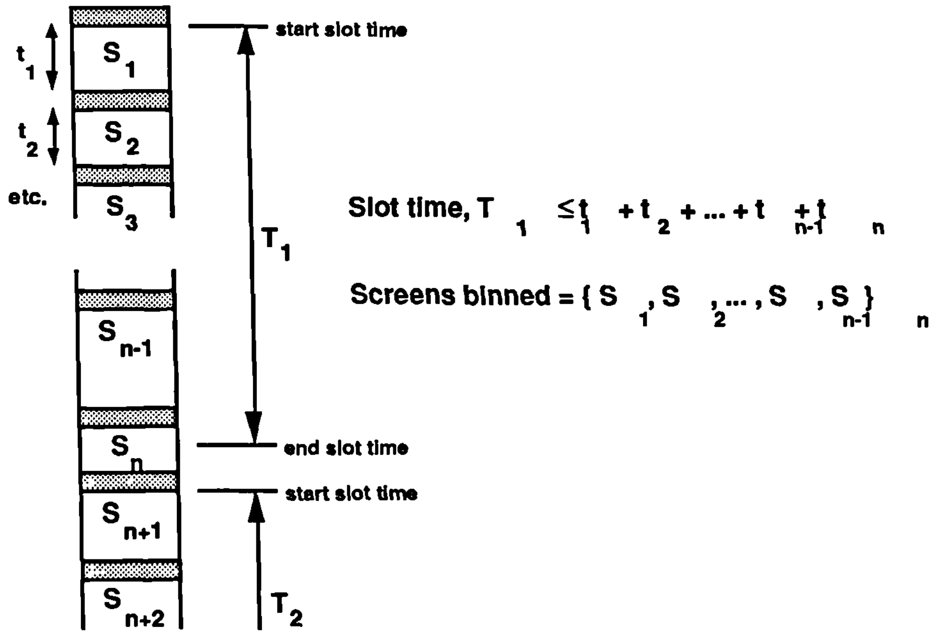


Figure 4.11 Graphical representation of the binning algorithm

A further utility program (called **combine**) was produced that permitted the individual output files produced by **logstat** to be merged. A typical output file is given in Figure 4.12. The figures for each screen type and slot totals are the averages of all the individual log-files *active* for that slot. With this program, it is possible to combine sessions of differing length.

```
E    H    I    M     N     P     Q    R    S     T     Total
0.0  0.0  0.0  0.25  7.0   1.13  0.0  0.0  0.75  0.0    9.13
0.0  0.0  0.0  0.63  6.88  2.13  0.0  0.0  0.63  0.0   10.25
0.0  0.0  0.0  1.25  7.7   2.13  0.0  0.0  0.5   0.0   11.38
0.5  0.0  0.0  2.13  6.13  1.5   0.0  0.0  1.25  0.0   11.50

Results derived from the following logs...
3, 8, 13, 18, 23, 28, 33, 38
```

Figure 4.12 Typical `'slot.all'` *file*

For example, four students (A,B,C,D) may each use the system for 11, 24, 36, 44 minutes respectively then the `slot.all` file, for five minute slots, would contain the following information:–

Time slot (5 minutes)	Data from students
1	A, B, C, D
2	A, B, C, D
3	B, C, D
4	B, C, D
5	C, D
6	C, D
7	C, D
8	D

The decreasing number of log-files used to generate this form of result as the slot number increases means that care must to exercised when applying statistical analysis.

As an example of the form of results obtainable, Figure 4.13 shows a typical log-file for one student from Study II. The first 120 minutes of interaction with the system are shown as a histogram of events. The ordinate represents ten minute time intervals, whereas the abscissa represents the number of interactions of a particular type that occur within each of these time slots.

This form of analysis shows the consistency, or otherwise, of system usage over time. It can be seen from these graphs that hypertext usage increased for this particular user, tours were used throughout the session, varying possibly with tour availability. Index shows fairly consistent use at around two interactions per ten minute slot. Map on the other hand was used very little. The graph for the use of the quiz shows that quizzes were used only after the student had spent 70 minutes exploring the information.

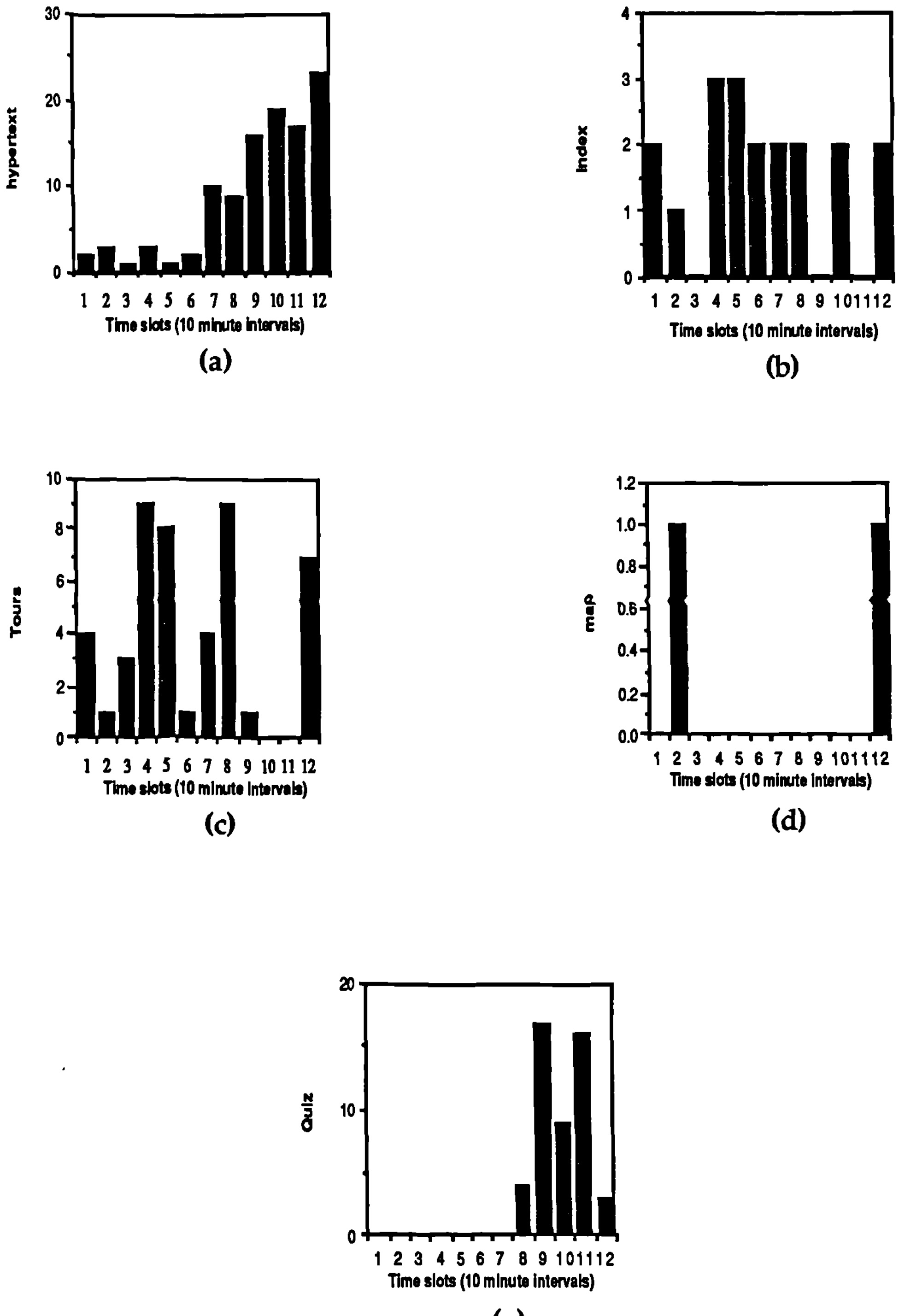


Figure 4.13 Typical longitudinal analysis of log-file

(The abscissa in each graph is the number of screens of the specified type seen in each ten minute time slot)

4.6.2 Results

Data from Study II was analysed using the utility program **combine**. This data effectively represents the averaged interaction of 20 students. Screen intervals rather than time slots were used for this analysis as the students' activity over a fixed number of screens is more appropriate since the length of sessions and rate of navigation through the screens was variable. Seven intervals consisting of 15 screens per interval were used, which represent the first 105 screens viewed. The resulting **slot.all** data file was used to plot the graph in Figure 4.14. It can be seen that the first 30 interactions, with the system, are dominated by tour navigation (this was the activation of the 'help' tour). Following this initial period, hypertext navigation becomes the main method.

More interestingly, it is useful to look at the differing interactions over time for individual users. Since these studies made no attempt to standardise the user's exposure to the system, it is not worth formally categorising individuals into various groups – each with their own distinctive style. A few examples will serve here, to illustrate these differences. The ordinate is, again, in terms of 15 screen intervals.

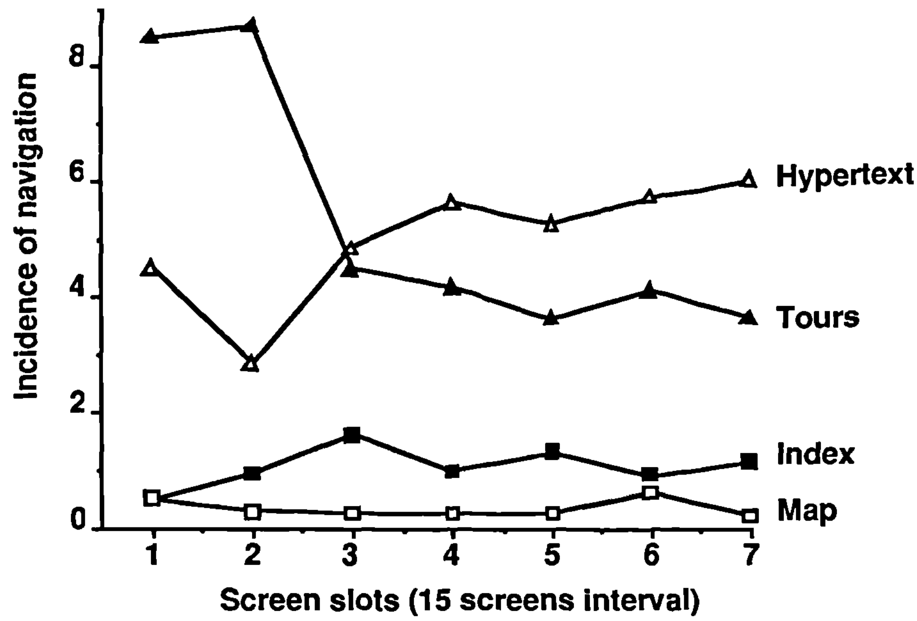


Figure 4.14 Consolidated system usage for 20 students in Study II

Figure 4.15 shows one subject (S76), whose interactions follow the averaged results, illustrated above, fairly closely. That is decreasing use of tours and a concurrent increase in hypertext usage. Figure 4.16 shows a subject (S78), who has employed the quiz facility both at the beginning and the end of a session – together with use of all navigation modes in the central information seeking region.

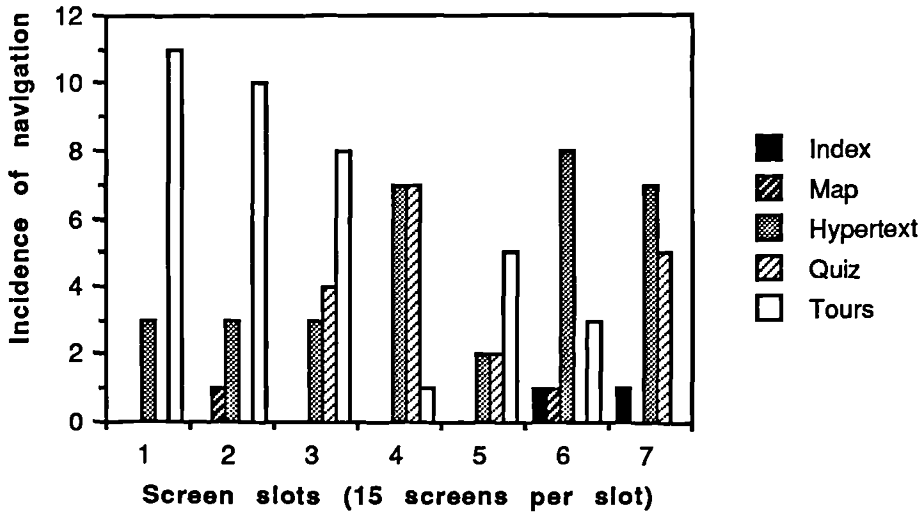


Figure 4.15 System usage for subject S76

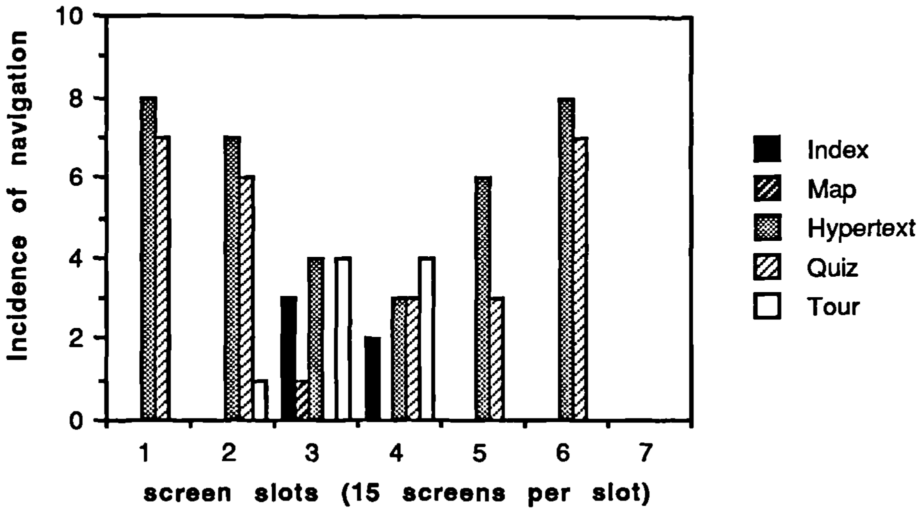


Figure 4.16 System usage for subject S78

(First 105 screens seen)

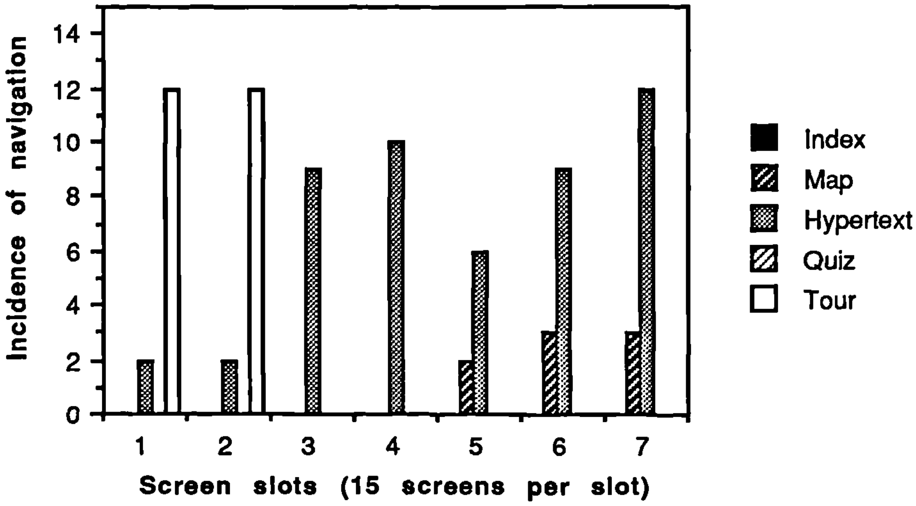


Figure 4.17 System usage for subject S72

(First 105 screens seen)

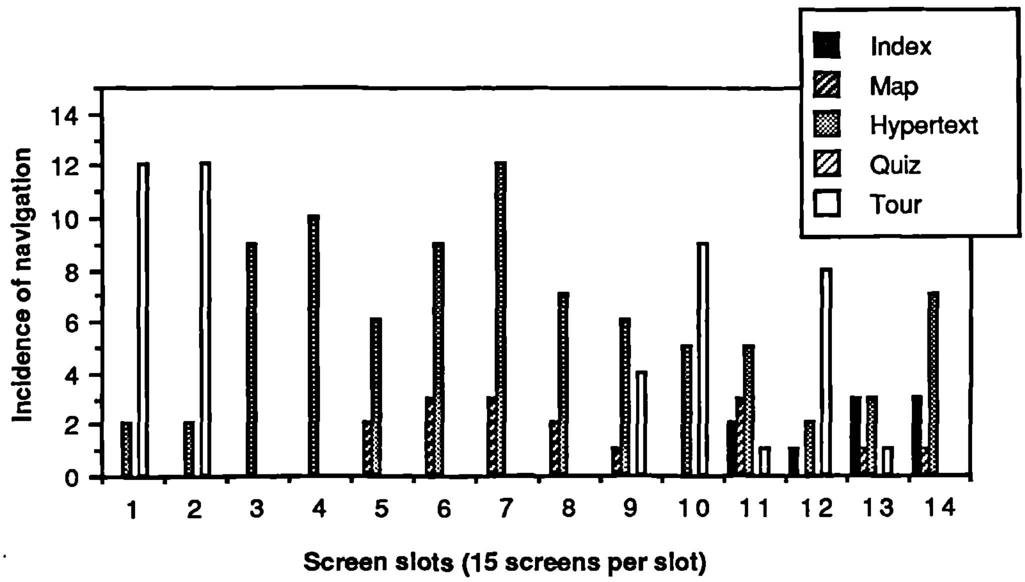


Figure 4.18 System usage for subject id 72

(First 210 screens seen)

Figure 4.17 appears to illustrate a user (S72), who relies on only a rather limited set of access methods in their first 105 screens. However, continuing the analysis to include his next 105 screens (Figure 4.18) shows that this subject did eventually employ all system facilities.

Extensive use of this type of log-file analysis will be undertaken in Chapter 5, where there were strict controls on user tasks and system exposure. However, this initial investigation demonstrated that major differences between users were observable.

4.7 Extended Questionnaire on System Facilities

4.7.1 Introduction

Some subjects from the second study were given a more detailed questionnaire. The purpose of this questionnaire was to see if these students understood the system and its facilities. From the log data, the majority of students appear to be using all of the system facilities. However this may not reflect appropriate use. The questionnaire, reproduced in Appendix B, was used to ascertain how much of the system functionality and rationale had been comprehended through actual use of the system. It would be interesting to know if the system functionality was indeed understood, and if students perceived this functionality in the way that had been intended at the system design stage. Students were asked to work independently on the questionnaires and were only identified by their passwords. It was important that the questions were answered in order, with no looking forward to proceeding questions or back to previous ones. This was emphasised in both written and verbal instructions to the subjects. Analysis of the questionnaire answers produced by the 13 students, who had used the system for a minimum of 30 minutes (at the time of the questionnaire), are given in this Section. A detailed analysis of Questions 1,2,3 and 6,7, 8 is given here. These questions are aimed at recall of system features. The other questions were more concerned with the issue of metaphor use. This aspect of questionnaire analysis is covered in Hammond & Allinson (1987). The students tested had not used the system during the preceding week, hence eliminating major differences between subjects due to recall of their most recent exposure to the system.

4.7.2 Results

The first question related to the travel metaphor, namely *"The microcomputer teaching system lets you look at a variety of material about cognition. What 'cover story' or 'model' is used to help explain how you get around the material?"* A travel metaphor had been introduced to aid system understanding and use. It could be argued that this metaphor should be well understood in order for it to be used efficiently. From the results (Figure 4.19) it can be seen that the majority of students had indeed discovered the travel holiday metaphor. Fifty percent giving precise descriptions and a further 33% using phrases such as 'travel guide'. Only 17% failed to give any appropriate description.

The second question, *"Write down all the different ways you can get from one 'screen-full' of material to another"*, simply elicited students recall of the available navigation methods. The better understood or dominant methods used by the subjects would most likely be recalled. The results are shown in Figure 4.20. Though this was a free recall task, there were very few responses that could not be unambiguously categorised. *Next*, *index* and *back-one* are seen to be the most prominent navigation methods, together with hypertext links. The *map*, however, was not recorded very often as a navigation method.

For Question 3, namely *"Write down all the different terms that appeared in the 'boxes' at the bottom of the screen"*, it was once again envisaged that the more meaningful (and probably the most used facilities) would be most often remembered. The results are shown in Figure 4.21. Here again, as with Question 2, *next* and *back-one* were most often recalled, followed by *index*, with *map* being remembered least. These results are consistent with the results of Question 2 and also consistent with the findings from the log-files. For the population from which this sample had been taken, *index* had been used significantly more than *map*. There is a high recall of *back-one*, again this is not surprising as heavy use of this facility was indicated in the log-files.

Question 6 identified the four different ways of accessing materials using the system:–

(a) Using the index
(b) Using the map
(c) Going on a tour (selecting a bus)
(d) Choosing your own route (selecting 'yellow' text).

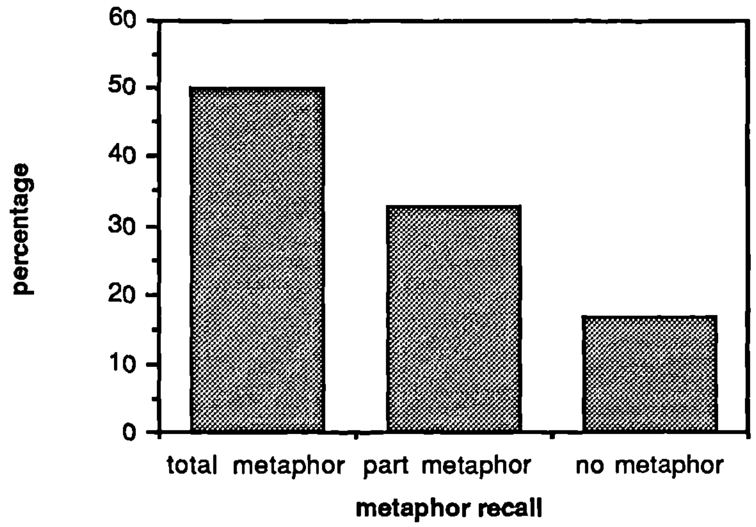


Figure 4.19 Percentage recall of travel metaphor

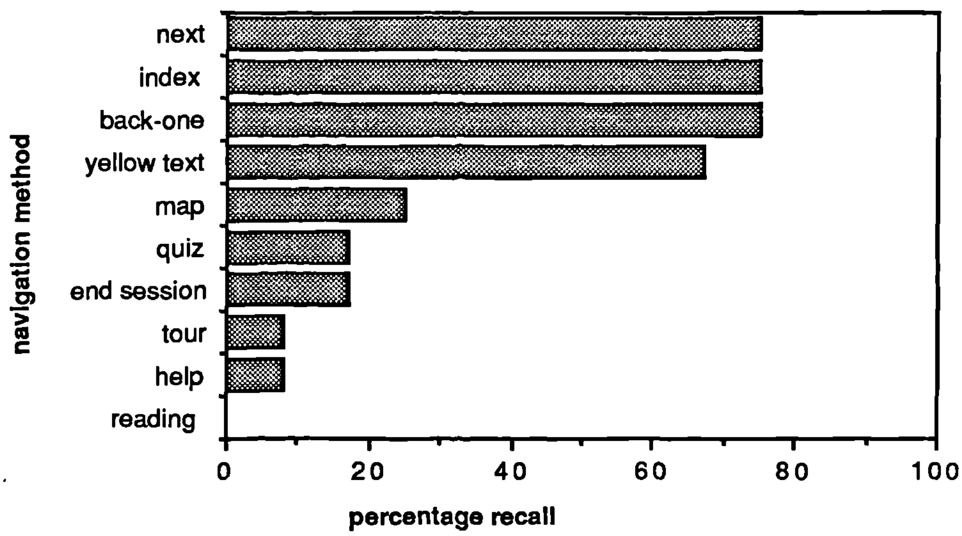


Figure 4.20 Percentage recall of navigation methods

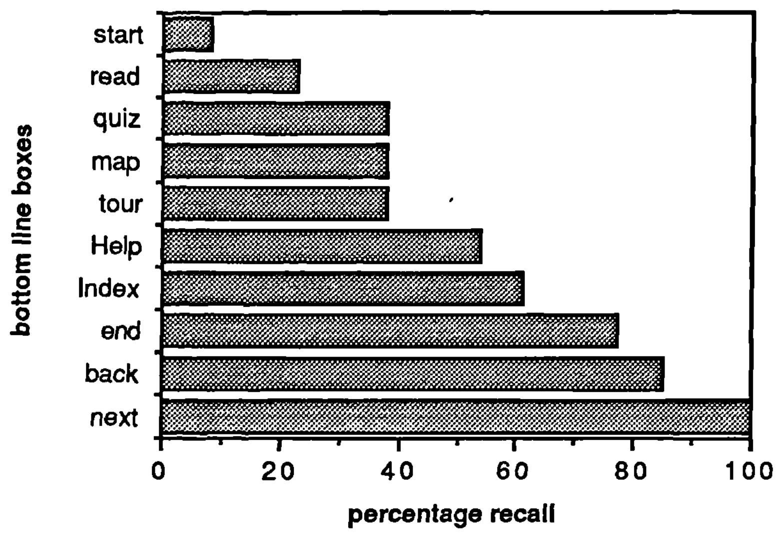


Figure 4.21 Percentage recall of bottom line boxes

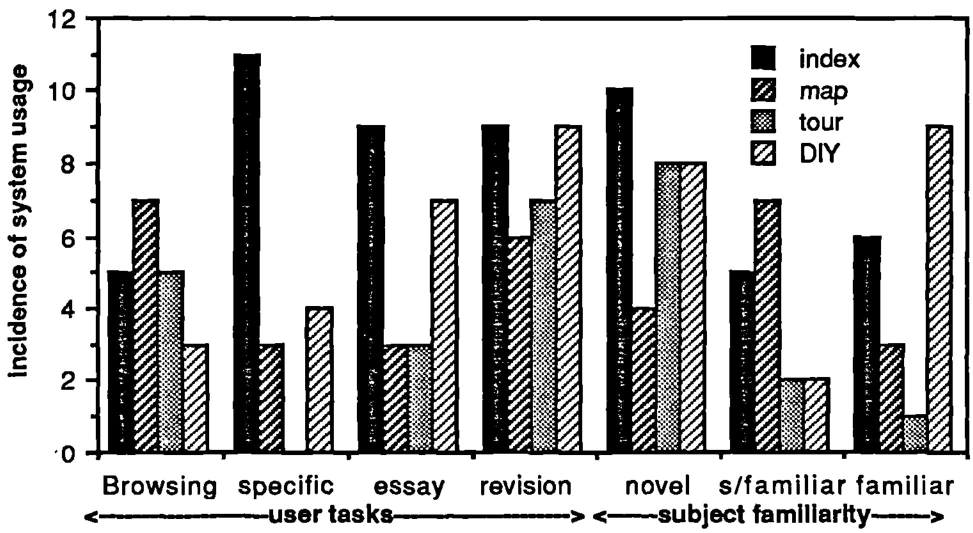


Figure 4.22 Reported incidence of system usage as a function of user tasks and subject familiarity

Subjects were asked to write one or more of these methods for each of a number of possible uses or the system, namely:–

1) When you know nothing about the material.
2) When slightly familiar with the material.
3) When familiar with the material.
4) When browsing through the material.
5) When getting material for a tutorial (e.g., for essay or notes).
6) When looking for other specific information (e.g., a reference).
7) When revising for an exam.

From Figure 4.22, it can be seen that most students (11 out of the 13) reported that they would use the *index* for finding specific information (such as a reference). *Index* would be used least for general browsing of material, or for material which was only slightly familiar. *Map* was the most favoured navigation method for both browsing and where the material was slightly familiar. Interestingly, *map* was least favoured for obtaining materials for a tutorial, searching for specific information, or for navigating familiar material. It seems that *maps* are not regarded as a direct access mechanism in the same way as *indexes* were. This may well be because the use of indexes is well understood and is a well practised skill, through the use of conventional textbooks. In addition to this, *map* usage may involve navigation between map screens and hence may not seem efficient for the purpose of information search. *Do-it-yourself* navigation, by selecting the 'yellow' text, is seen to be most useful when navigating familiar materials. This is possibly because with familiar material, a lot of the uncertainty of the effects of selecting hypertext links has been removed. Also, the student has an idea of the material contained in the system and would be more likely to endeavour to locate this. Having more knowledge of the inherent structure of the material should help the user of a hypertext system where a large number of highly branching links have been used. Predictable findings are found for the use of *tours*. *Tours* are used for the navigation of novel materials and for revision. They are not seen to be useful where the materials are familiar to the student or where specific information is being sought. The general impression is that students possessed a good understanding of the navigation methods and their appropriate application.

The final two questions asked students to:–

- Order the usefulness of the four methods (*index*, *map*, *tour* and own route).
- Order their actual use of these four methods.

Figure 4.23 shows the results obtained. The columns are obtained by summing the rankings obtained from the orderings. For example, if *index* was most often ranked first (most useful or most often used) the resulting sum across all students would be the least. In fact, this is the case, *index* achieves a significantly lower score (i.e., higher ranking for both questions). The high similarity of the answers to these two questions suggest that students do believe that they are using the system appropriately. The higher use of *index* over *map* can certainly be seen from the log data, but log-file analysis is not sensitive enough to differentiate other usage. The problems of the analysis of log-files will be discussed in the next section.

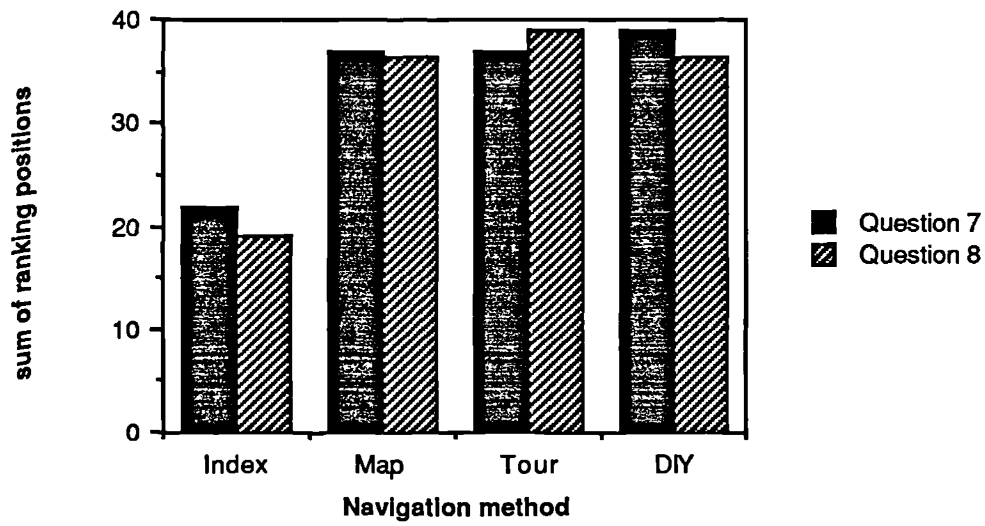


Figure 4.23 Graph of recalled usefulness and usage of navigational facilities

4.8 Discussion

The system evaluation described in this chapter used a number of methods to gain insight on the usability and usefulness of the Hitch-hiker's Guide. The methods used were:–

- passive observation
- analysis of system log-files
- questionnaires.

Passive observation was found to highlight very little by way of system usability. This was probably due to the passive nature of the observation. It had been intended that students learn the materials in a naturalistic environment. We could not expect to highlight the user's conceptual model of the system if we constrain the development of that model with the system designer's model. If we are to design usable systems then we have to design to match the cognitive expectations of the user. Testing the system interface was not the subject's goal, as they were engaged in real study activities. It would have been inappropriate to have interrupted this. To have done so would have told us more about system usage at the expense of system usefulness.

System log-files provide a wealth of information. The computer is an ideal vehicle for recording events at this level of detail. From the log-files we were able to reconstruct a user session, following user paths and strategies. For example we can identify how long a subject has spent on the system, their favoured approach or strategy for knowledge acquisition, search or retrieval. At a finer level of analysis, the logs can show detailed styles of use, for example in the case of the quiz screens, use of multiple choice questions (which act as advance organisers) and embedded tours can be clearly traced. Although log-files produced a substantial amount of the information for these evaluations, this data is not without its problems. The main problem is just how much we should read into these data without knowledge of the precise user intent at any point in the interaction. Did the subject who started but failed to complete a tour intend this or even realise it had happened? Can the log-file identify successful parts of the session interaction from sequences of activities that may have left the user confused and disorientated? More generally, how can we tell if the student is really learning anything. If we do not know the precise learning goal that the student is engaged in, then we have no way of evaluating attainment of this goal. This obviously leaves us in a dilemma. Active intervention in a true learning situation may adversely effect the learning process yet this intervention appears essential in order to analyse the log-files in fine detail and with accuracy.

Questionnaires are an attempt to provide some sort of compromise for this dilemma. They are not a complete answer as they are retrospective views, and hence once again are able to isolate coarse features only. In this sequence of evaluations, we collected data from two questionnaires. The first questionnaire related to system usage and gave general feedback on the usability of the system (How easy? etc.), and also on the usefulness (How successful? How soon a next visit?). The second questionnaire attempted to find out how well the system had been understood within a comparatively short period of use. The first questionnaire, given to all subjects, showed the user interface to be easy to use and that use of the system was found to be successful. The second questionnaire tried to establish that these general findings were on the basis of understanding of the system. It could be quite feasible for a subset of the available features or, in fact, a very limited style of interaction to be similarly regarded as successful or easy. If subjects understood the system features and their appropriate use, we could be more certain of the successful design of the interface. It was clear from the second questionnaire that this was indeed the case. Subjects were able to discriminate between different user goals and attribute appropriate navigation methods to them. What was extremely interesting was the low recall for the map facility and of its inclusion as a navigation facility. Clearly here the *map* is not being regarded as a superior facility. For this second group of subjects index was the preferred method, as shown by the log data. Once again we must return to the old problem of user intent. The second group of users had more specific goals associated with their system use. Without a very clear idea of the user goals, the actual usage as reported in questionnaires or collected in log data, cannot accurately reflect true user perceptions and usage. Another point worth noting is that the results were collected during the early exposure to the system. Would the findings differ after a much extended exposure to the system?

It is clear from these preliminary evaluations that although many of our evaluation objectives have been met by our chosen methodology, still many more have not. The system has proved to be easy to use and popular with the students. It meets many of the students' requirements. Software and hardware have been tested and feedback resulted in necessary system changes. Many interface issues were addressed but issues of navigation were only partially addressed. Students used all navigation methods and appeared to use these appropriately, but evidence does not exist to show how navigation methods relate to tasks undertaken. It may well be that subjects guessed the intent of the extended questionnaire and gave the expected responses. Though even this suggests some understanding of the system.

Finally, what the preliminary evaluation had not attempted to do was to evaluate educational goals and outcomes of the use of hypertext-based systems. Evaluation of this kind was outside the scope of these initial investigations, but this must be a major issue that needs to be addressed before hypertext systems can be used extensively within computer-based teaching.

CHAPTER 5

THE 'YORK' EXPERIMENT

5.1 Introduction

Our preliminary evaluations described in Chapter 4 played a vital role in highlighting salient areas for research and potential methods of analysis. The data collection and analysis were not subjected to rigorous experimental practice and, hence, provided only insights into some facets of usage of the system. By the end of this evaluation phase, however, the system proved itself to be both stable and robust. The interface had been thoroughly tested, and the system was receiving significant student usage and positive feedback from the questionnaire responses. The shortcomings of the various methodologies for user evaluation had been illuminated.

The earlier studies demonstrated that all the four main navigation facilities (hypertext links, maps, indexes and tours) were widely utilised after only a short exposure to the system. The extended questionnaire responses, outlined in Chapter 4, suggested that the students were employing the facilities in an appropriate task-directed manner. An experiment was required to show if this was indeed the case. For this it was necessary to control the learner task in such a way as to have knowledge of the students' intentions and goals (a known shortcoming of the preliminary evaluations). In order to monitor 'appropriate' facility use, it was necessary to restrict the available access tools and to measure the resultant performance in the various restricted conditions. Although development of the system had been based on various psychological principles (see Chapter 3), the increased functionality provided by the multiple navigation methods may have had hidden costs. Catrambone & Carroll (1987), with their training wheels interface model, show that reduced functionality during the learning phase can in the longer term lead to better performance. It was also envisaged that the students' view of the system would reflect the limitations or otherwise of the particular mix of access mechanisms available.

The experimental design was therefore to provide novice users with different sets of access facilities, and to look for any resulting systematic differences between the groups which would indicate improved access or structuring of the materials to be learnt. If this could be shown for novice users, then it would also be likely that experienced users could be shown to benefit from the presentation of the appropriate system facilities. For novice users it was felt appropriate to use simple factual materials that allowed many cross references and, hence, a rich navigation network. It cannot however be extrapolated that with rather more complex materials, with greater inherent structure, learners would have shown similar patterns of system usage, but it is quite likely that the various access tools would have indeed proved more beneficial. To emulate two likely system uses and to provide a focus for the learners' activity, subjects were tested in either a free learning (*exploratory-task*) or an information retrieval (*directed-task*) paradigm.

5.2 Methodology

5.2.1 Subjects

The subjects used in this study were 80 paid adult volunteers who were all visitors to York. They were attending an Open University Summer School and most were studying the Foundation Level Technology Course. Forty-eight subjects were male, 32 female, and their age range was estimated to be 25 – 55 years.

5.2.2 Materials

An information network provided information on the history, buildings, streets and museums of the City of York. This topic was chosen as it could be illustrated by the use of bit-mapped graphics to produce colourful and interesting screens with a careful balance of graphics and text. Presentation of too much text would have led to either too much material to learn, or insufficient screens with which to test the various navigational methods. Also, since the subjects were visitors to York, the material would have been both novel and of interest to them.

The network contained 45 information screens as illustrated in Figure 5.1 (this representation shows only the *direct* linkages and not the numerous cross references between screens). Of these only 39 contained *real* information (i.e., they contain topographical information about some aspect of York) as six of the screens were introductory or simply presented a series of choices to the reader. An example of the latter type is shown in Figure 5.2, and is a screen giving options for further exploration of the different historic buildings in York. This screen is embedded in a hierarchical part of the network.

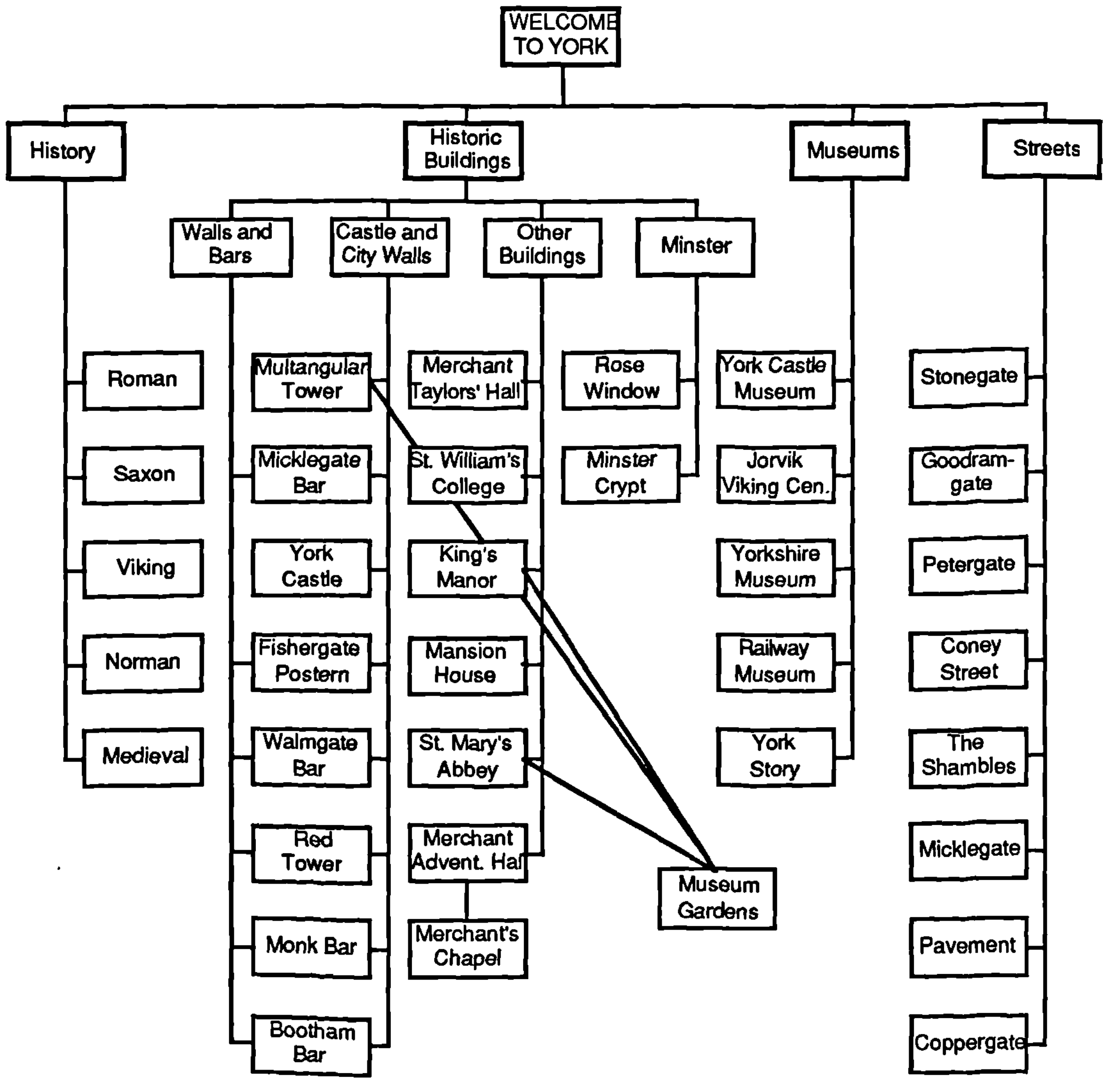


Figure 5.1 General network for the York Guide material

The logical structure of the source material often determines the initial hierarchy of the hypertext. Until at a greater depth in the information base, a more general network structure of linked screens becomes appropriate. These screens can in themselves become 'mini-indexes' and as such can be used as a focal point for navigation around the material. A similar screen, this time containing some information, is shown in Figure 5.3. Four screens from the 'Streets' section are shown in Figures 5.4 to 5.7.

Associated with the information screens were five *navigation* screens – an index screen providing routing to all 39 information screens from 42 entries, three map screens providing routing to all information and choice screens (see Figures 5.8 to 5.10), and a preliminary screen from which guided tours were available. This last screen consisted of five coaches denoting the start of tours and also a option for *go-it alone* (hypertext) navigation. The five tours had an average length of nine screens.

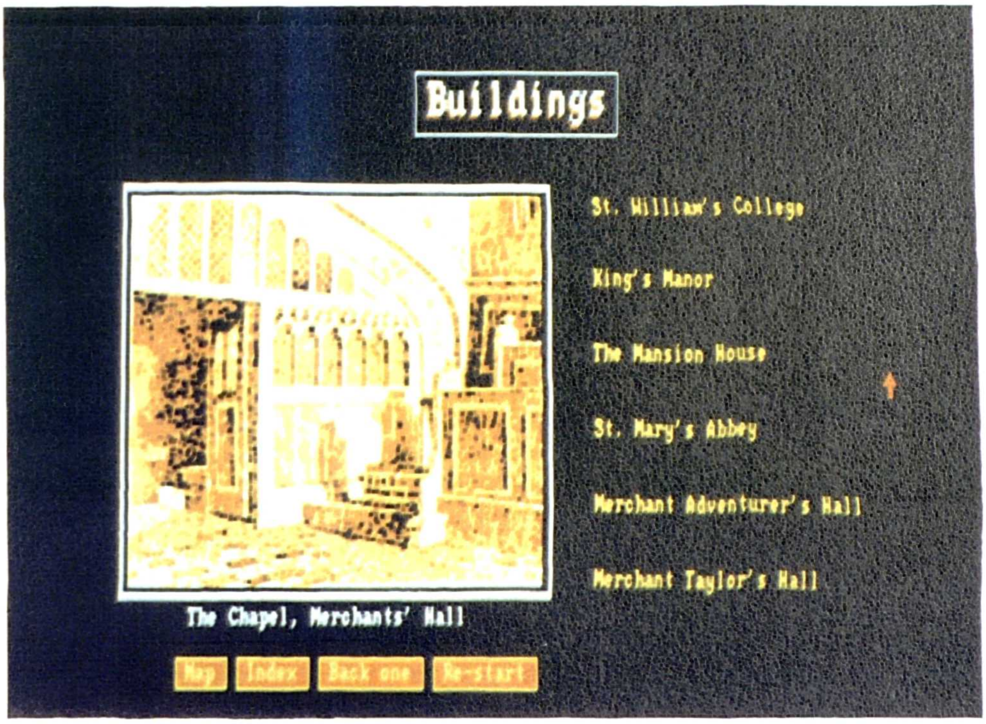


Figure 5.2 'Buildings' sub-menu screen from the York Guide

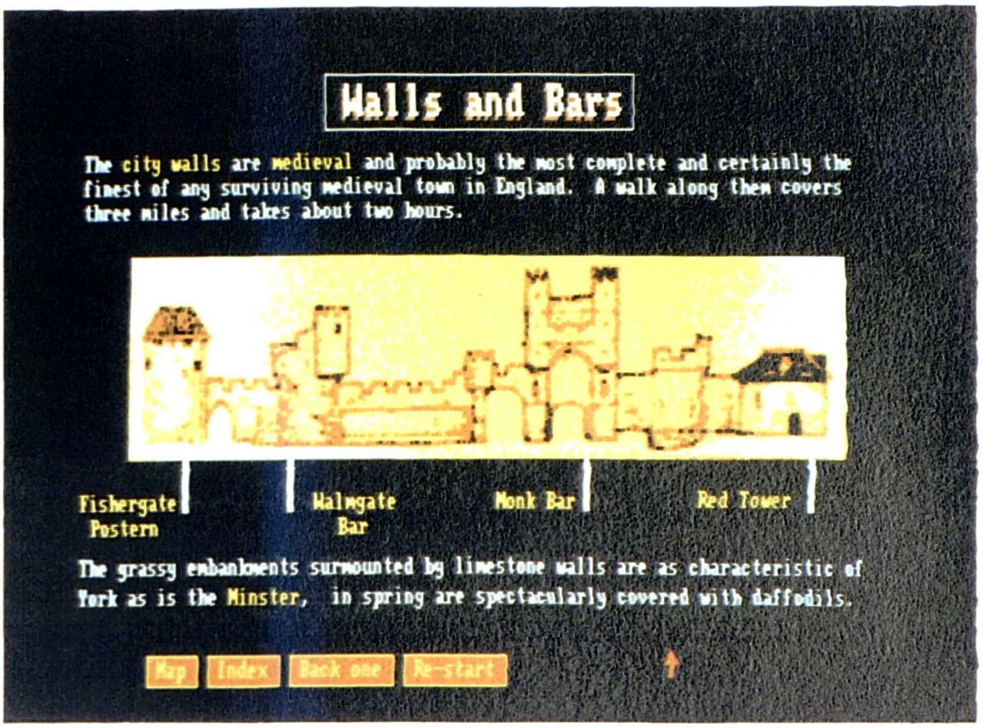


Figure 5.3 'Walls and Bars' screen from the York Guide

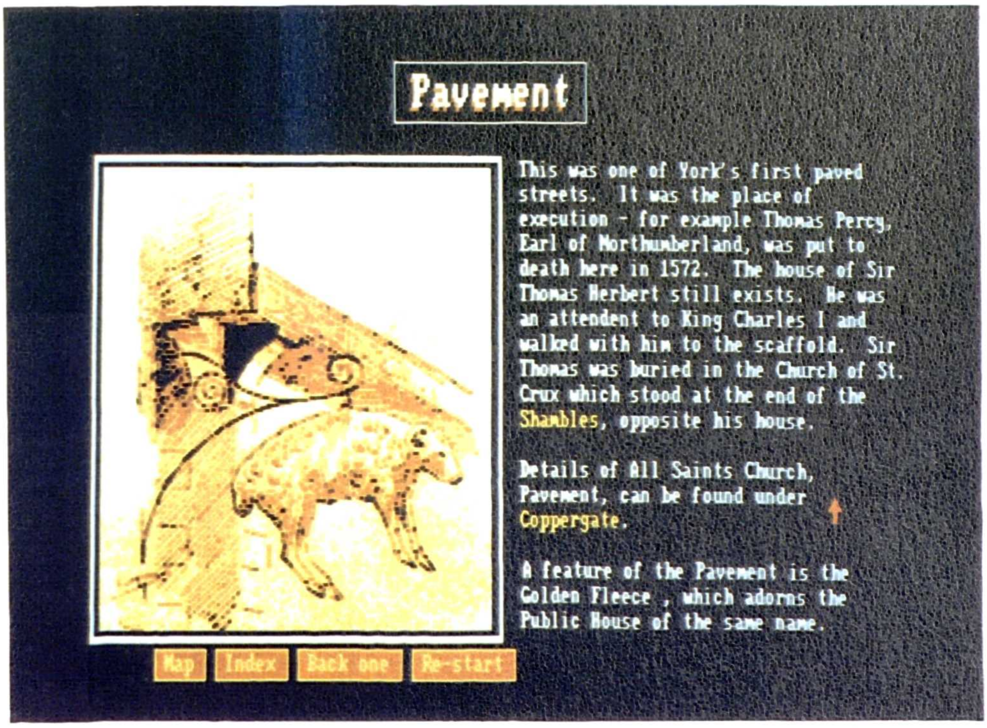


Figure 5.4 York Guide street information screen – Pavement

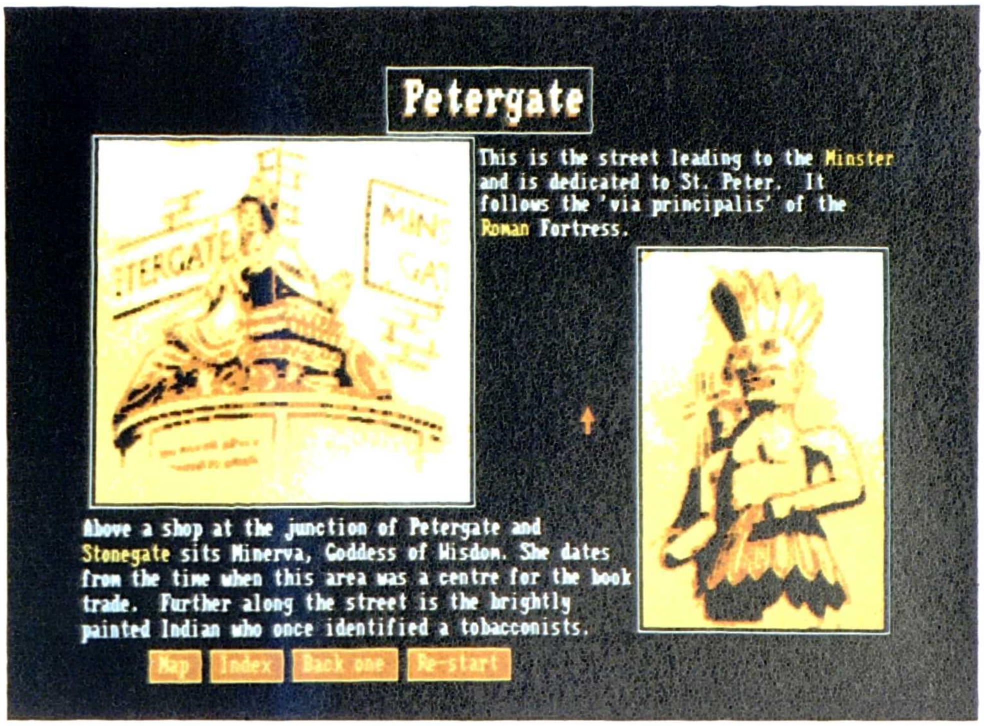


Figure 5.5 *York Guide street information screen – Petergate*

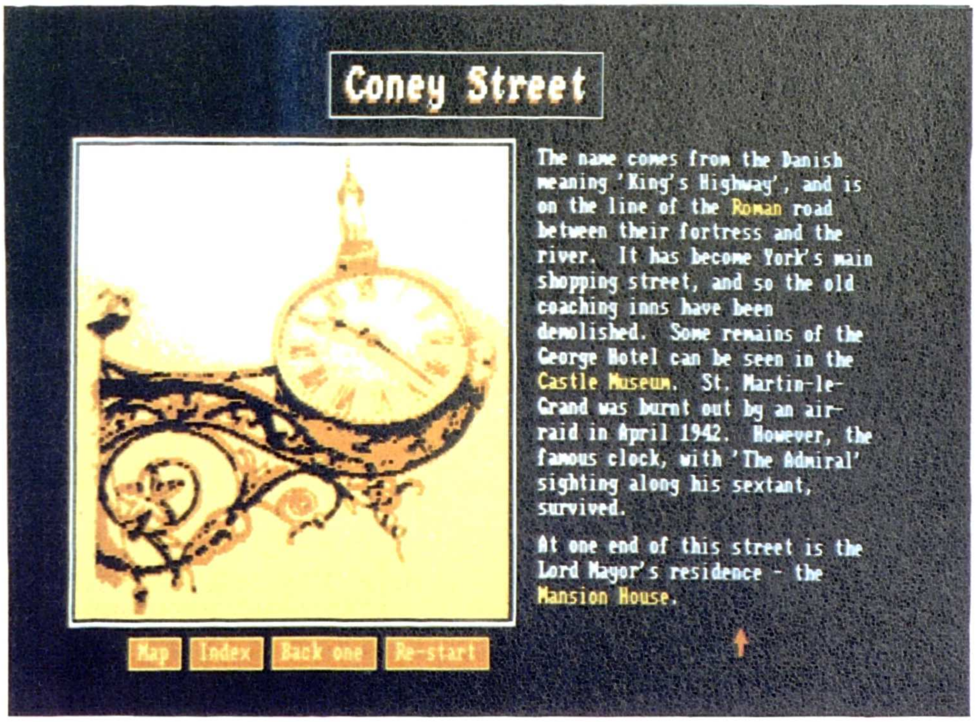


Figure 5.6 *York Guide street information screen – Coney Street*

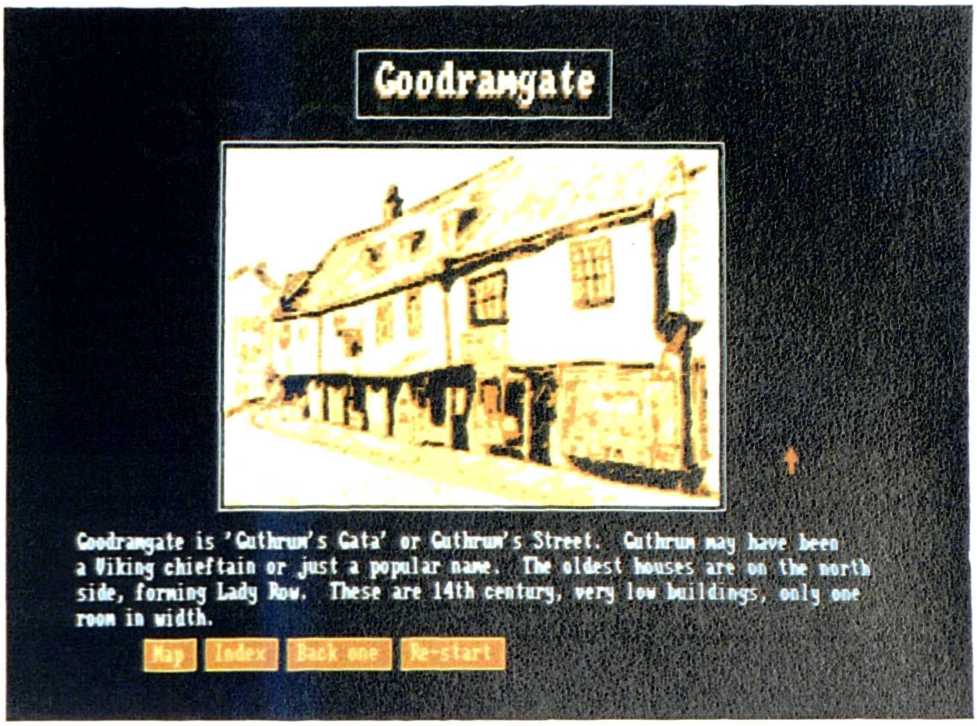


Figure 5.7 York Guide street information screen – Goodramgate

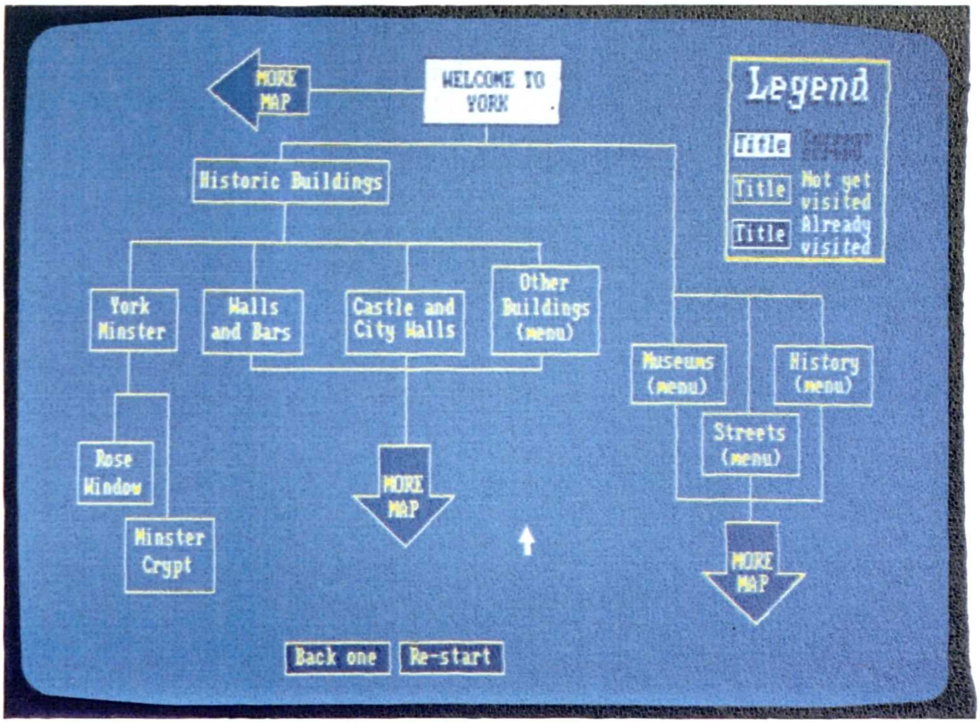


Figure 5.8 First map screen from the York Guide

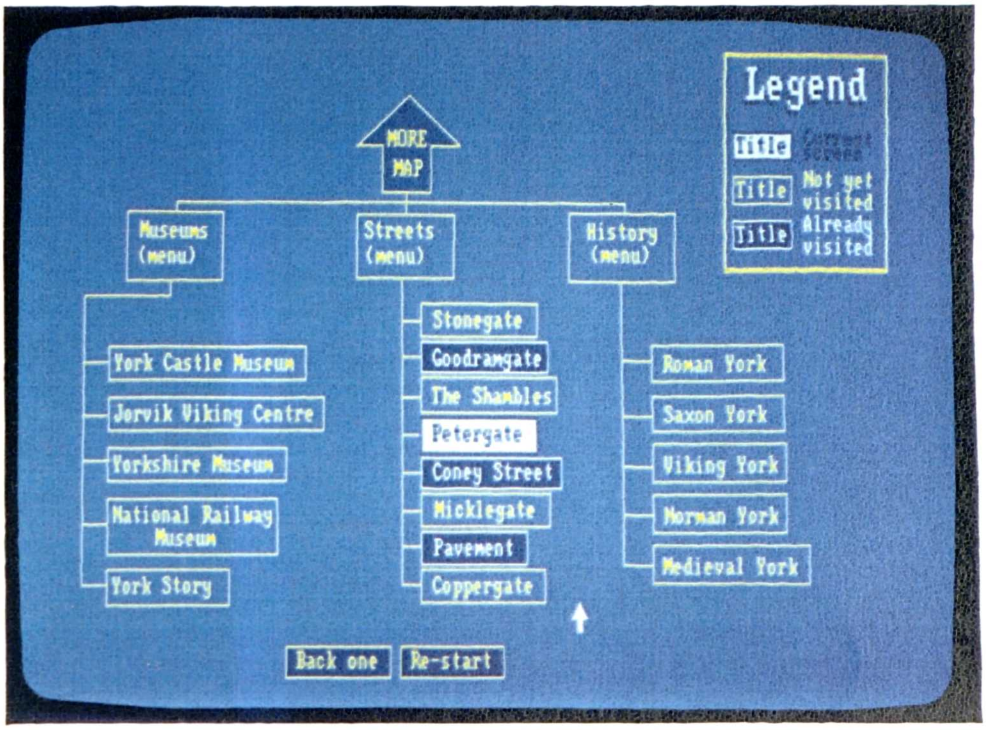


Figure 5.9 Second map screen from the York Guide

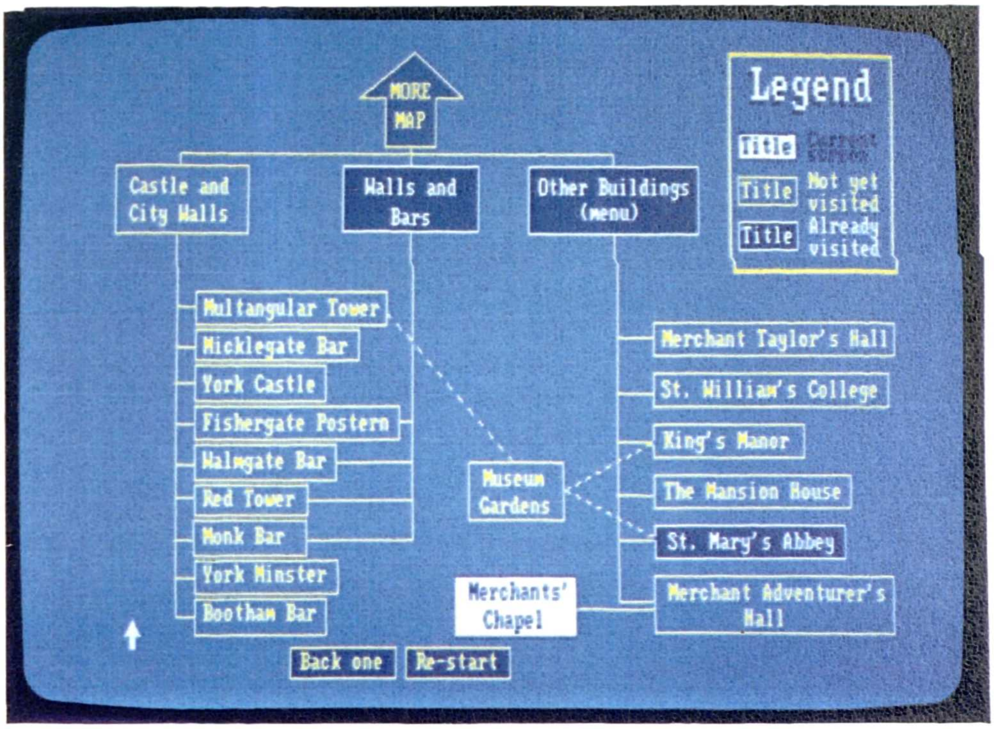


Figure 5.10 Third map screen from the York Guide

Note: Footprinting on all map screens.

5.2.3 Procedure

Subjects were randomly assigned to one of two groups. Both groups were given the same materials to study. For the first group, the *exploratory-task* group, the instructions were to cover as much of the material as possible in preparation for a multiple-choice questionnaire (given in Appendix C). This questionnaire contained 50 items and gave questions based on isolated factual knowledge presented in the information network. The second group, the *directed-task* group, were given a booklet of ten questions (extracted from the questionnaire) and their instructions were to answer these questions in the order presented. For this second condition, screen numbers were presented at the top right of the screen so that the information frame could be uniquely identified. This screen number was required as well as the completed answer, thus eliminating any guessing of the correct answer. This provided a check that the information was extracted from the correct screen, rather than from inferences made from related information. Taking a specific example from the test material, Coppergate is the site famous for the excavation of a Viking settlement, yet the 'Coppergate Helmet' found at the time of these excavations was Saxon in origin. These items of information were provided on different screens. Hence, analysis of these answers could provide information on the source of errors.

These two groups were further divided into five conditions differing in the access facilities available. A listing of these different facilities is given in Table 5.1.

Table 5.1 Facilities available in each of the five conditions.

Condition	Facilities available
H	Hypertext
HI	Hypertext, Index
HM	Hypertext, Maps
HT	Hypertext, Tours
HIMT	Hypertext, Index, Maps, Tours

Subjects in each group were given verbal instructions on how to use their particular version of the system and an instruction sheet, giving navigational instructions for their specific version only, was available throughout the experiment. A sample instruction sheet is given in Appendix D. Subjects were asked to try all facilities offered to them. Subjects who failed to utilise an additional facility, for example one subject in the HM condition who failed to access a map, were removed from the later analysis. There was no training session provided.

Subjects were given 20 minutes of system use. The *directed-task* group could have finished earlier if all the tasks had been completed. To minimise the possibility of this, Question 10 was particularly difficult as it was open-ended and required more of a search strategy than simple retrieval. Subjects were then given a five-item rating-scale questionnaire concerning their experience of the system (given in Appendix E). Following completion of this questionnaire, the 50 item multiple-choice questionnaire was given to members of the *exploratory-task* group only.

5.3 Results

Data was derived from the following three sources:–

- The performance log-files collected by the system
- Task performance via the analysis of the 50 item questionnaire and ten item task-orientated questions
- The subjective questionnaires.

5.3.1 Performance logs

The log files produced were analysed using the utility program **`logstat`**, detailed in Chapter 4. Analysis of variance using $SPSS^X$ statistical package was performed on the data produced in the resultant **`rest.$`** files (see Chapter 4 for details). The data collected can broadly be grouped into three types; firstly, global parameters, such as time spent on the system (not relevant to this experiment) and various screen counts. Secondly, measures relating to the navigation strategy used (for example percentage of back-one interactions of the total system interactions) and finally, measures that give some measure of efficiency. The measures employed in this study are listed below, together with their abbreviations.

Global measures*

Total screens seen	TSS
Total novel screens seen	TNS
Total information screens seen	TISS – (i.e., TSS - navigation screens)
Total novel information screens seen	TNIS

Navigational strategy measures

Percentage use of back-one	P
Percentage use of re-start	S
Percentage use of hypertext links	N
Percentage use of bottom-line boxes	BLB

Efficiency measures

Total novel screens as percentage of total screens seen	A
Total novel screens as percentage of total possible screens	B
Total information screens seen as percentage of total screens seen	C
Total novel information screens as percentage of total information screens seen	D
Total novel information screens as percentage of total possible information screens	E

Not all of the above measures will be reported in detail here, though the full analyses (two-way between analysis of variance and Tukey's Honestly Significantly Different test) are given in Appendix F. In the following sections, significant differences, identified by the HSD test, are taken at the $p \leq 0.05$ level.

Finally, the log data was analysed, using **`logstat`** and the resultant **`slot.$`** data files (as described in Chapter 4) to determine how patterns of navigation developed

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* **Note on Notation**
Information screen refers to a screen containing topographical details, as opposed to screens which function as simply introductory, indexes or maps.

Total novel screens refers to the number of different screens that have been accessed, and total screens refers to total number of screens that have been accessed regardless of repetitions.

'P' (for previous) refers to back-one as in the log-files 'B' refers to single button presses. 'N' (for next) refers to conventional hypertext links as in the log-files 'H' refers to *Help* access.

during system usage either between the two conditions (*exploratory-task* and *directed-task*) or as a function of provided facilities within the *exploratory* or *directed-task* itself. The utility program `combine` was used to produce the time-averaged facility usage over time for the two conditions. Here we are particularly interested in the development of specific facility usage and need to look more closely at the different patterns of usage developed during usage of a specific facility, for example the use of map (HM condition), and any differences that might be dependent on the task. For this, two-way split-plot analysis using $SPSS^X$ was carried out on the specific facility pairs. Full tables of these analyses are given in Appendix G.

5.3.2 Global measures

Our expectations are that the *directed-task* group would employ a general strategy of searching for the answers to the supplied questions and give less effort in attempting to learn the material. The opposite would be the case for the *exploratory-task* group.

The total number of screens seen (TSS) by the two groups is significantly different at the $p < 0.001$ level. ($F(1,70) = 20.41$, $MSE = 184.57$), indicating a greater rate of navigation through the screens in the *directed-task* condition (see Figure 5.11). This reflects their task goals as the instructions for the *directed-task* group were to retrieve information rather than to learn it. The differences found for task in the H and HM, HT and HIMT conditions are significant at the $p < 0.05$ level using the HSD test. There was no significant difference of task in the hypertext and index (HI) facility condition.

Task has little effect on the total number of novel screens seen (TNS), differences in the means are not significant (see Figure 5.12). The highest number of novel screens was viewed in the HT condition. In the *exploratory-task* group this was significantly higher than for any other facility condition. In the *directed-task* group, total novel screens (TNS) seen in the HT condition is significantly higher than all other facility conditions with the exception of the hypertext and map condition (HM). For the *exploratory-task* group, the least number of screens seen was in the hypertext only condition (significantly less than the other four facility conditions), whereas in the *directed-task* group the HI condition was significantly different from all other facility groups with the exception of the hypertext-only facility condition. For the *directed-task* group, use of this index facility indicates more efficient access to the required materials. For the *exploratory-task* group, use of the tour indicates a more efficient access to the required materials. For both task groups, the hypertext-only (H) condition led to poor coverage of the materials. As this was particularly important for the *exploratory-task* condition, hypertext may well be more suited to directed rather than exploratory use since coverage using hypertext-only systems is reduced.

Although the *directed-task* group saw a significantly greater number of screens during the 20 minute interaction, this does not reflect a significantly greater coverage either of the available screens (TNS) or of actual information screens (TNIS). This once again reflects the task requirements of the *exploratory-task* group to cover as much of the material as possible, and was obviously dependent upon where the answers to the questions were situated within the information base. Once again, as with total novel screens there is a significant difference in coverage of the information screens (TNIS) between the hypertext (H) and hypertext and tour (HT) conditions for the *exploratory-task* group. These subjects saw the fewest information screens in the hypertext-only (H) condition and saw the most in the hypertext and tour (HT) condition (see Figure 5.13).

A summary of these results is provided in Table 5.2.

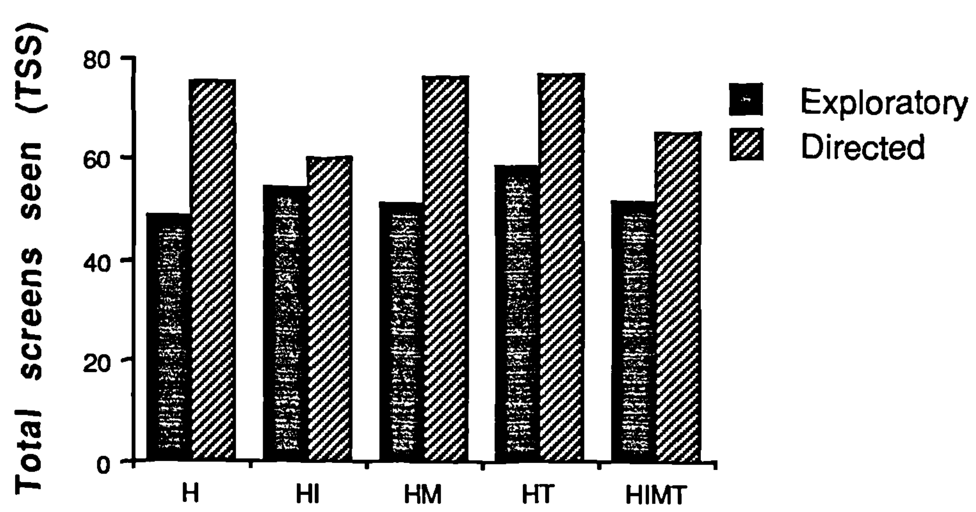

Figure 5.11 Total screens seen for each facility condition and task group

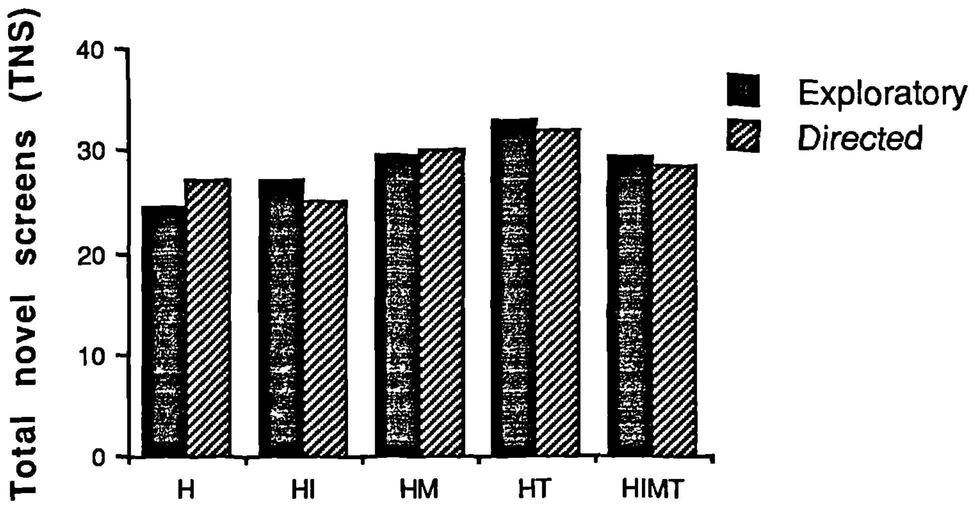

Figure 5.12 Total novel screens seen for each facility condition and task group

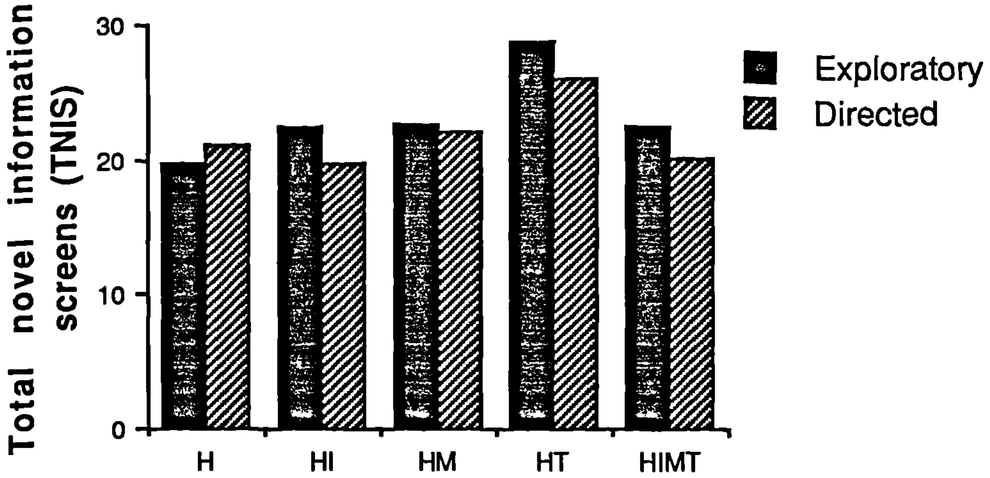

Figure 5.13 Total novel information screens seen for each facility condition and task group

Table 5.2 Results summary for global measures

Measure	Task	Facility	Task x Facility
TSS	***	ns	ns
TNS	ns	**	ns
TISS	*	***	ns
TNIS	ns	**	ns

Notation: ns – p > 0.05
* – 0.01 < p ≤ 0.05
** – 0.001 < p ≤ 0.01
*** – p ≤ 0.001

5.3.3 Navigational strategy measures

The measures analysed here are for those facilities that are common to all facility groups. These are use of restart, back-one, hypertext links and bottom-line boxes. Other strategy measures, such as the percentage use of index, map and tour facilities are not dealt with here but in Section 5.3.7, as these are facility dependent measures.

The percentage use of restart and back-one facilities are easiest to detail. It could be assumed that the re-start facility would be used either when lost in the system (i.e., in order to return to a familiar base screen) or simply to return to a launch screen in order to start a new information search (or restart a failed one). We would expect the first case to hold for the *exploratory-task* group, and perhaps the second case to be a strategy adopted by the *directed-task* group. A significant difference was found for task groups, ($F(1,70) = 6.28$, $p < 0.001$) and also a significant effect of facility condition ($F(1,70) = 4.95$, $p < 0.05$). From Figure 5.14, it can be seen that the *directed-task* group used restart to a greater extent for all facility conditions. The HSD test reveals this difference to be significant in the hypertext (H) and hypertext and tour (HT) facility conditions. For *exploratory-task* group, the restart facility was used most often with the hypertext-only system (H) and least with the full facility system (HIMT). This does not reach the $p = 0.05$ level of significance using the HSD test, but would suggest that the provision of the addition facilities does help to avoid *getting lost* in the information. There is a significant effect of facility in the *directed-task* condition, once again the hypertext-only facility condition (H) resort more often to the re-start facility and the full facility (HIMT) condition the least.

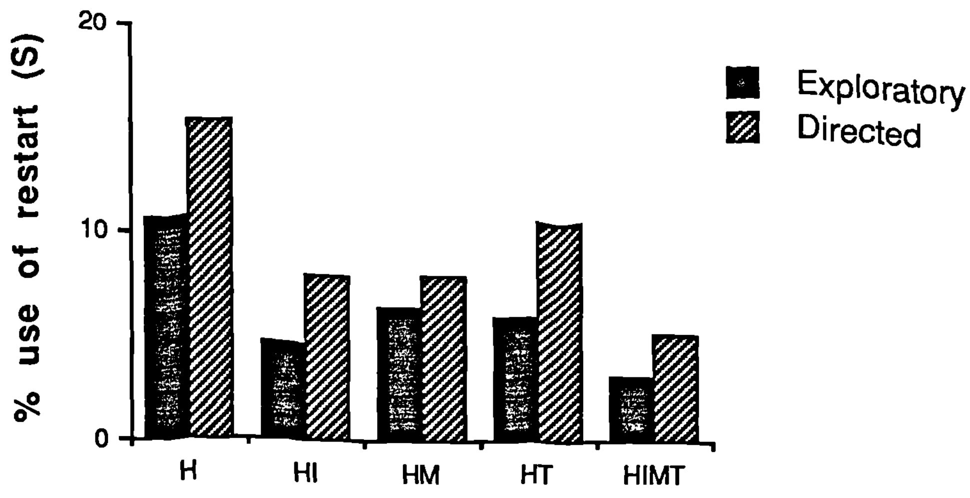

Figure 5.14 Percentage use of restart for each facility condition and task group

The back-one facility, which provides a simple aid to navigation and orientation within the materials, shows the pattern of usage given in Figure 5.15. Despite the generally higher percentage use of this facility for the *directed-task* group there is no significant effect of task ($F(1.70) = 0.43$, not significant). The only significant difference is for the effect of facility ($F(1,70) = 3.62$, $p < 0.01$). However, Tukey's HSD fails to reveal significant differences between the facility conditions for either the *exploratory-task* or *directed-task* group. Figure 5.15, however, does show that the hypertext-only (H) condition makes the greatest use of the back-one facility, followed by the hypertext and index (HI) condition. As expected these two facility conditions provide the least aid to orientation, hence simple back-tracking has to be adopted as a key navigational mechanism.

Use of hypertext navigation and bottom-line boxes is confounded by their differing availabilities across facility groups. Hence only task differences will be reported here (see Appendix F for full statistical analysis). Figures 5.16 and 5.17 show the percentage use of these facilities – hypertext navigation and bottom-line boxes respectively. Note that for these two graphs, the percentage use of hypertext and bottom-line-boxes sum to 100% for the first three columns only. For the HT and HIMT conditions, the treatment of tour use as a third category of user activity means that the respective columns do not sum to 100%.

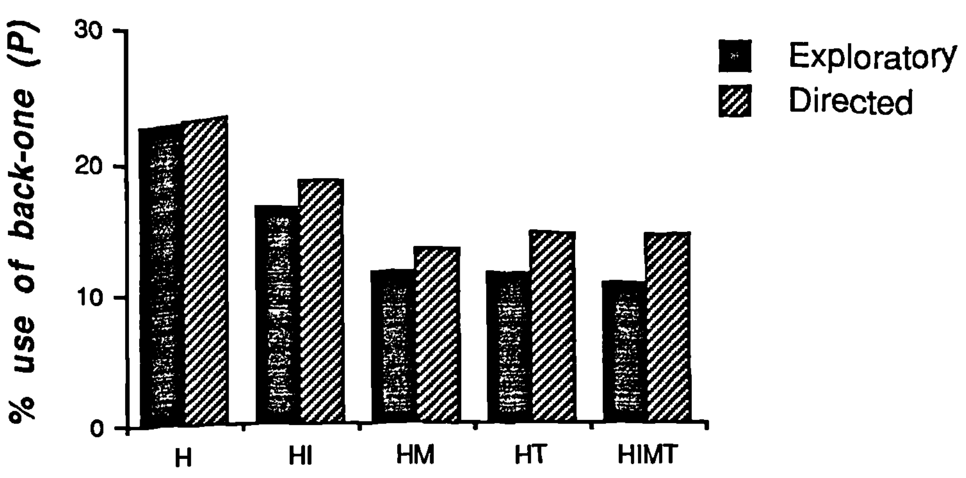

Figure 5.14 Percentage use of back-one for each facility condition and task group

There is no significant effect of task on the percentage of hypertext navigation (F(1,70) = 2.08, not significant). There is however a significant effect of task on the percentage use of the bottom-line boxes (F(1,70) = 7.71, $p < 0.01$). Further analysis using the HSD test reveals significant differences of task in both the hypertext and tour (HT) condition and the full (HIMT) condition. The *directed-task* group utilised the available bottom-line box facilities to a greater extent than the *exploratory-task* group. Unfortunately, a measure of bottom-line box usage is difficult to explain and may simply reflect the increased usage of restart and back-one as already shown. It could also reflect a reduced usage of tours in the *directed-task* condition. We must also take care in using measures that record the percentage occurrence of some parameter, as the percentage increase in one parameter can result in a corresponding decrease in some second parameter – though the actual number of occurrences of this second parameter may not have changed.

5.4 Efficiency Measures

Efficiency can be regarded in one of two basic ways. Firstly, efficiency can be the viewed as coverage of the available materials – a subject who sees 95% of material available in the system can be regarded as a more efficient user than a subject who sees only 70%. Secondly, a system can be regarded as efficient if it allows coverage of the materials with the least number of screens viewed (i.e., least number of navigations). Inefficient coverage hence occurs if the user is subjected to a large amount of unnecessary repetition of the information screens viewed.

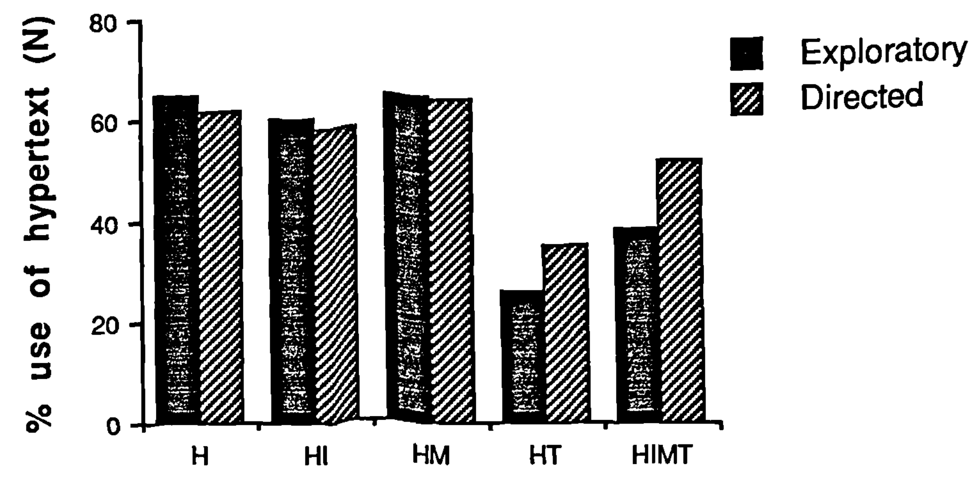

Figure 5.16 Percentage use of hypertext for each facility condition and task group

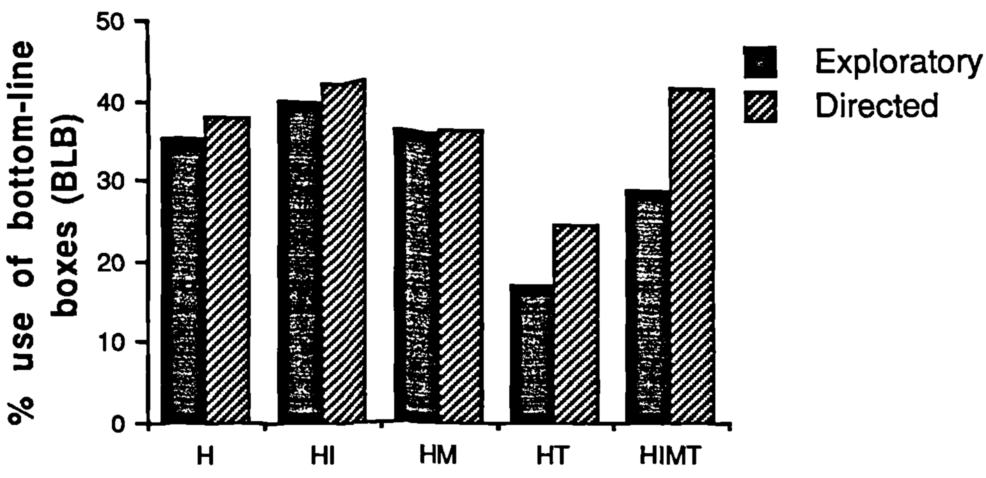

Figure 5.17 Percentage use of bottom-line boxes for each facility condition and task group

The data collected from the log-files contains efficiency measures of both types. Variables B and E (i.e., total novel screens as a percentage of total possible screens, and total novel information screens as a percentage of total possible information screens, respectively) measure the former. Variables A, C and D (i.e., total novel screens as a percentage of total screens seen, total information screens seen as a percentage of total screens seen, and total novel information screens as a percentage of total information screens seen, respectively) measure the latter. Although full analyses of each variable is given in Appendix F, only an example from each of the two basic efficiency measures will be presented here.

5.4.1 Efficiency of coverage

The results for variable B and C are very similar in their patterns across task and facility, showing no significant effect of task but a significant effect of facility condition. The graph of results for variable E (i.e., total novel information screens as a percentage of total possible information screens) is given in Figure 5.18. since this represents the percentage of the actual information screens that were viewed.

It can be seen from this graph that the higher percentage of information screens were seen in the hypertext and tour (HT) facility condition and the lowest in the hypertext only (H) facility condition (for the *exploratory-task* group only). This difference is found to be significant using the HSD test. For the *directed-task* condition however, Tukey's HSD revealed no significant differences although once again the HT facility condition led to the highest coverage whilst the HI facility condition lead to the lowest coverage. These efficiency measures need careful interpretation however as efficiency for the *directed-task* group would in fact be the opposite to that for the *exploratory-task* group. The former should see the lowest number of screens in order to answer the supplied questions for an efficient system; whilst the latter should see all of the information screens if the system is to be judged efficient. The hypertext and index (HI) facility condition represents the most efficient system for information retrieval and the hypertext and tour (HT) facility condition the least efficient.

5.4.2 Efficiency of navigation

The total number of information screens seen as a percentage of total information screens provides a good measure of the level of repetition encountered during system usage. This measure is chosen for comparing facilities as it does not include the navigation and choice screens that would necessarily be dependent on facility availability. Analysis of this variable produces a significant effect of both task ($F(1,70) = 40.36$, $p < 0.001$) and facility ($F(1,70) = 4.30$, $p < 0.01$). This measure is illustrated in Figure 5.19.

Tukey's HSD shows task to be significant for all facility conditions with the exception of the full (HIMT) facility condition. Once again this reflects task goals. The two *task groups* need to be considered separately with regard to facility condition differences. For the *exploratory-task* group it can be seen that the hypertext and map (HM) facility condition was the most efficient. A high percentage (mean value of 83%) of all information screens seen were novel screens. This finding is as expected as the *footprinting* provided by the map facility should alleviate unrequired repeat visits to information screens. The finding that the hypertext and tour (HT) facility condition is the least efficient (the HSD test indicates that the difference between the HM facility condition and the HT facility condition to be significant) is more puzzling. Tours should be the most efficient (for this material) as each tour contains a unique set of screens. The low efficiency measure suggests that tours were repeated, possibly because the navigational efficiency of tours allowed time for this.

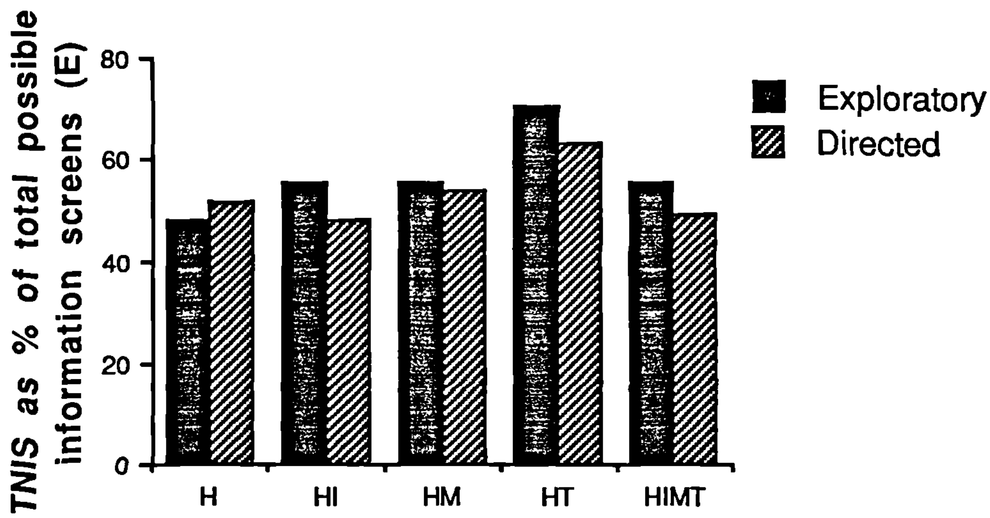

Figure 5.18 Total novel information screens as a percentage of total possible information screens for each facility condition and task group

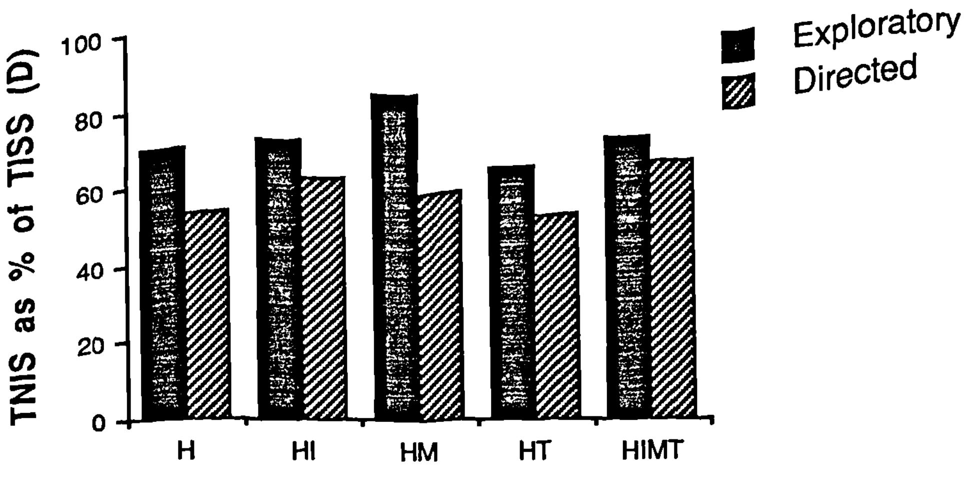

Figure 5.19 Total novel information screens as a percentage of total information screens seen for each facility condition and task group

Efficiency measures for the *directed-task* group are less meaningful without an understanding of the hypertext structure and location of the answers to the task-directed questions. Once again however, using tours (HT facility condition) gives the lowest efficiency measure whereas the full (HIMT) facility condition gives the highest efficiency measure. This is a most pleasing finding indicating that provision of the full facility system leads to more efficient navigation. Unfortunately, using Tukey's HSD, none of the facility condition differences is found to be significant for this *directed-task* group (The difference between HT and HIMT are however very close to significance at the $p < 0.05$ level - see Appendix F).

5.5 Longitudinal Analysis

The previous sections analysed general data collected from the log-files, however a two-way between analysis of variance on certain of the data variables collected was inappropriate due to the varying nature of facility provision. For example, analysis of the percentage use of the index facility is only appropriate for those facility conditions were index is presented (HI and HIMT). This section will therefore deal specifically with the analysis of data specific to each facility condition, that is the use of hypertext in the H condition, of index in the HI condition, of map in the HM condition, of tour in the HT condition and of all these facilities in the full HIMT condition. For this investigation, the log-files from the experiment were analysed by the utility program `logstat` to produce the longitudinal data-files **slot.$**. The log-files were segmented into time intervals rather than screen numbers. This was considered more appropriate as all students spent the same amount of time using the system. Five minute interval slots were chosen, resulting in four intervals for each subject. Data from the eight subjects in each of the ten groups were subjected to an analysis of variance to determine if there were any significant differences in the temporal patterns of system usage either between the two conditions (*exploratory-task* and *directed-task*), or within the *exploratory* or *directed-task* conditions themselves. Full analysis of variance tables and appropriate Tukey's HSD tests are given in Appendix G.

5.5.1 Hypertext only (H) condition

This two-way split-plot analysis of variance demonstrated a significant difference between the groups for the use of hypertext in the H group ($F(1,14) = 13.02$, $MSE = 11.53$, $p < 0.01$), indicating increased system usage in the *directed-task* condition (see Figure 5.2). Significant differences were also found for hypertext usage over time ($F(3,42) = 3.72$, $MSE = 2.31$, $p < 0.05$). The results are shown in Figure 5.20. Further analysis (i.e., Tukey's HSD test) shows a significant increase for the *exploratory-task* group in hypertext usage in the first 5-minute interval and the final time interval (representing usage from 15 minutes to 20 minutes of experiment duration.). The pattern is not so clear for the *directed-task* group, hypertext navigation shows a significant increase of the third time interval over the previous two, but the final time interval measure shows a decline in hypertext usage.

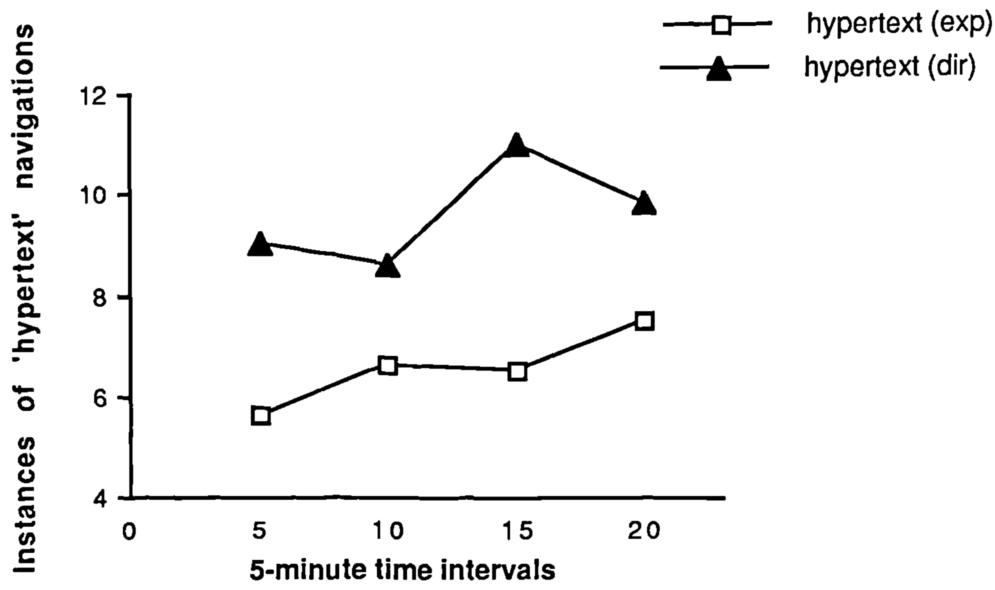

Figure 5.20 Longitudinal use of hypertext navigation for Hypertext -only (H) facility condition)

5.5.2 Hypertext and index (HI) and hypertext and tour (HT) conditions

No significant difference were found in the use of the *index* in the HI facility condition (see Figure 5.21) or the tour in the HT facility condition (see Figure 5.22)

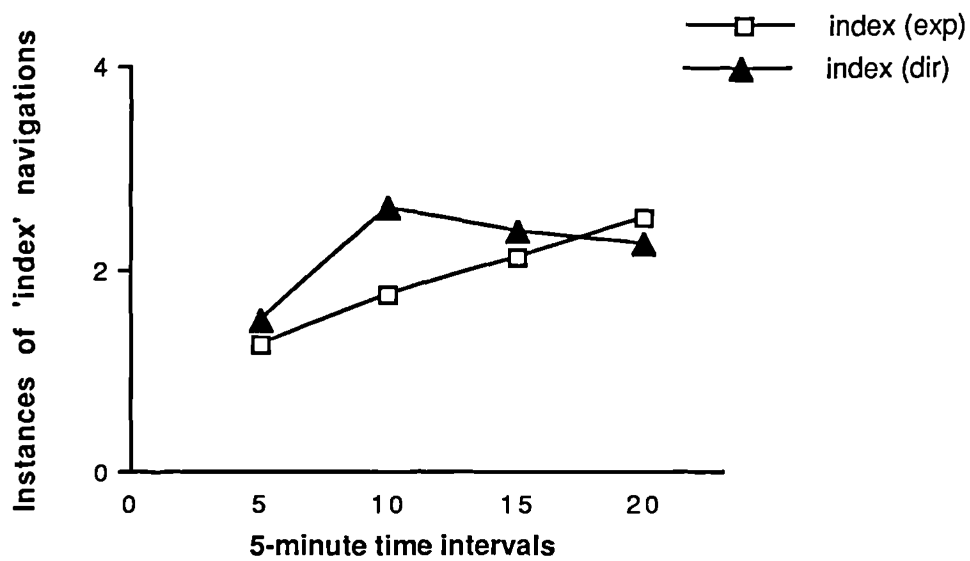

Figure 5.21 Longitudinal use of index navigation for Hypertext and index (HI) facility condition)

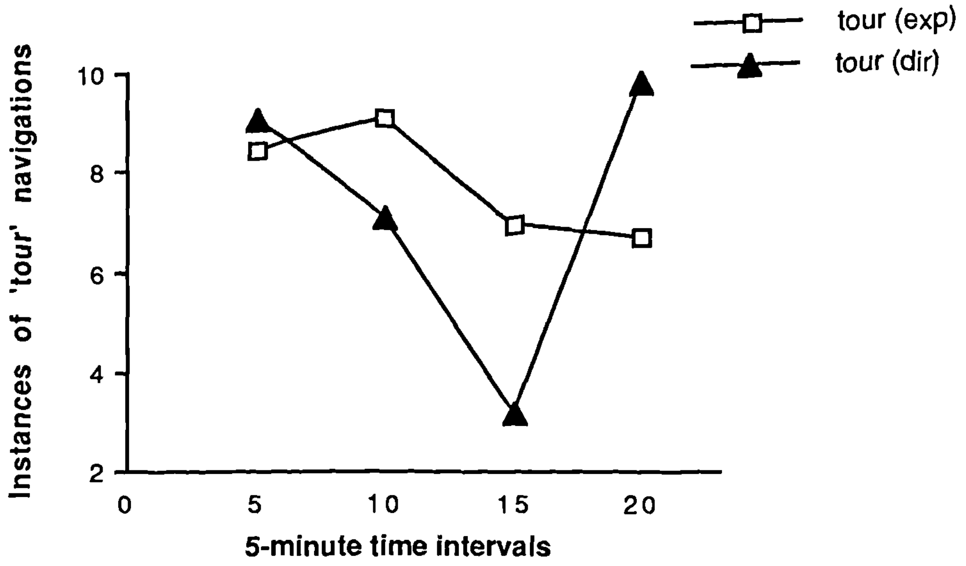

Figure 5.22 Longitudinal use of tour navigation for Hypertext and tour (HT) facility condition)

5.5.3 Hypertext and map (HM) condition

There was no significant task differences found with the use of the *map* facility (HM condition). There was, however, a significant difference for facility usage over the four time intervals ($F(3,42) = 5.66$, $MSE = 3.42$, $p < 0.05$). Figure 5.23 shows the temporal pattern of map usage for the *exploratory-task* and *directed-task* groups (HM). Use of analysis of variance is, perhaps, suspect due to the very small number of map navigations recorded in each time interval.

5.5.4 Full facilities (HIMT) condition

Analysis of the HIMT condition produced interesting results. Significant differences between *exploratory-task* and *directed-task* conditions were found in the use of the *tour* facility ($F(1,14) = 5.51$, $MSE = 18.60$, $p < 0.05$) and the use of the *index* facility ($F(1,14) = 11.53$, $MSE = 3.39$, $p = 0.004$). The tour facility was used significantly more by the *exploratory-task* group, and the index significantly more by the *directed-task* group. There was no significant differences between the task groups in map or hypertext usage, although, for hypertext usage the analysis of variance was close to significant ($F(1,14) = 4.36$, $MSE = 26.50$, $p = 0.056$), indicating increased usage of hypertext navigation in the *directed-task* condition.

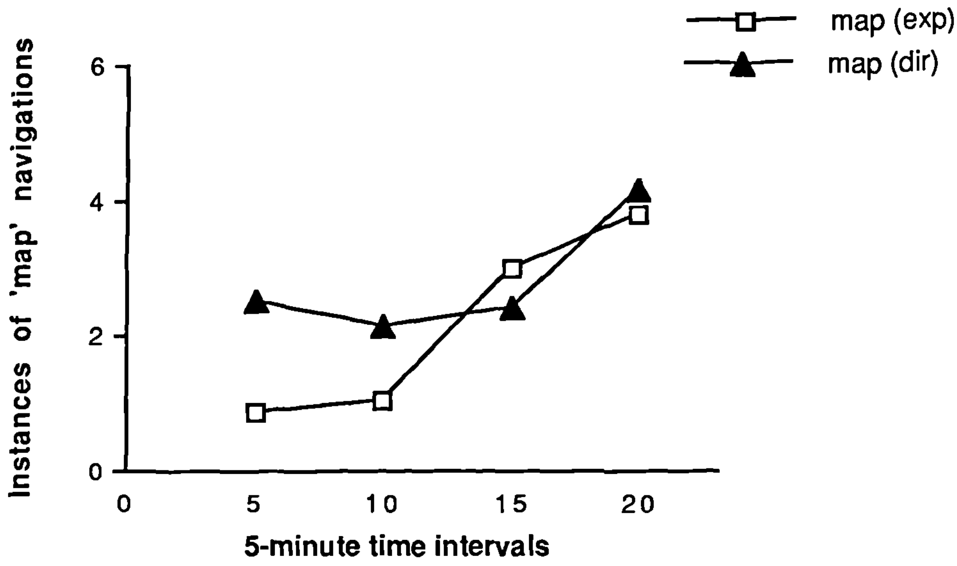

Figure 5.23 Longitudinal use of map navigation for Hypertext and map (HM) facility condition)

The analysis for this HIMT condition revealed no significant differences over the different time intervals for *hypertext, tour* or *index* use. A significant difference was found for *map* usage over time ($F(3,42) = 3.74$, $MSE = 1.08$, $p < 0.05$). This would indicate the consistent use of the *index* facility throughout a session, but the increasing use of the *map* facility during the session. Figures 5.24 and 5.25 show the temporal patterns of navigational facility usage for the *exploratory-task* and *directed-task* groups respectively.

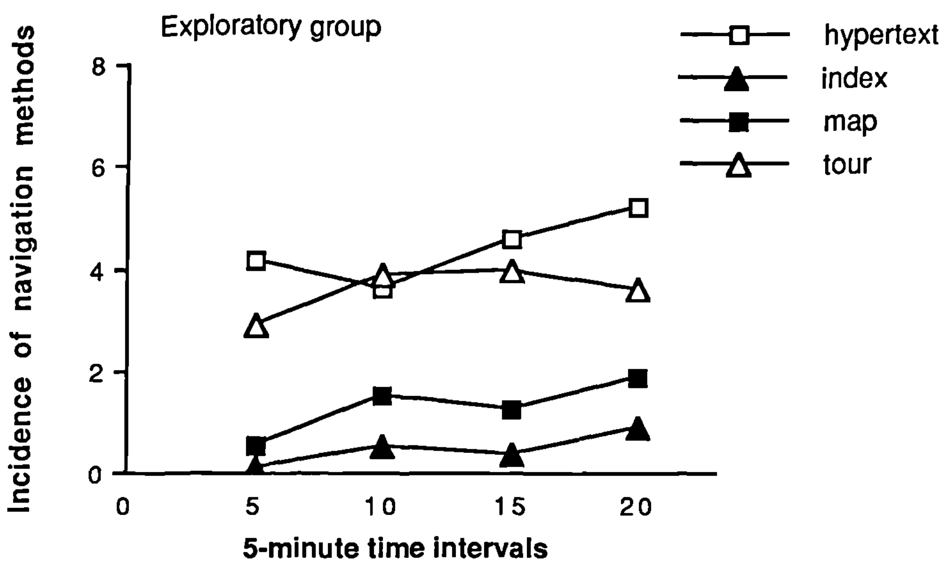

Figure 5.24 Navigational usage over time for the exploratory-task (HIMT facility condition)

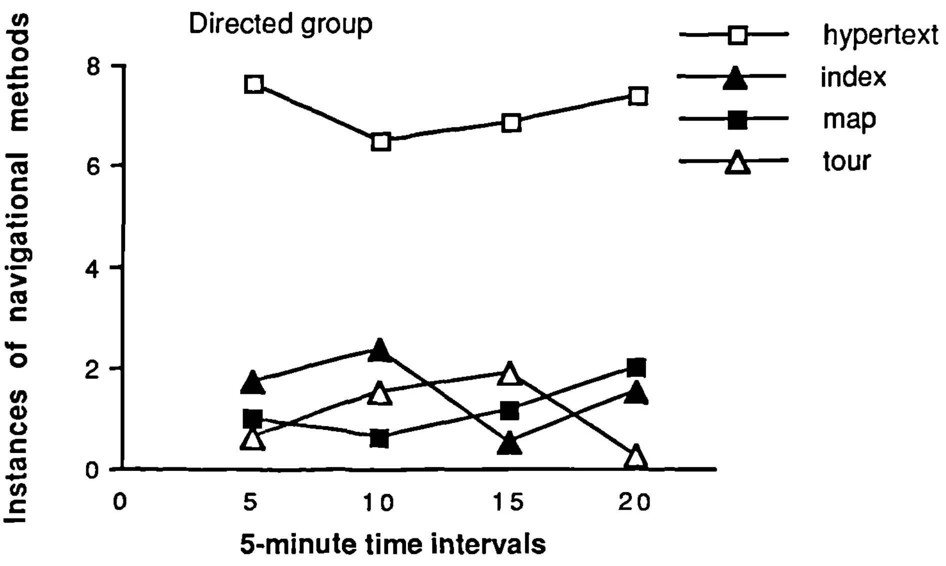

Figure 5.25 Navigational usage over time for the directed-task (HIMT facility condition)

5.6 Task Performance

5.6.1 Exploratory-task group

The 50 item multiple-choice questionnaire was scored for the number of correct answers. The means and standard deviations for each group are given in Table 5.3. Analysis of variance produced no significant differences.

*Table 5.3 Mean scores on the 50 item questionnaire, and the ratio of these scores to total information seen(*exploratory-task *group)*

Group	Mean score (σ)	Total novel info screens (TNIS) (σ)	mean score / TNIS
H	15.25 (±4.17)	19.75 (±3.20)	0.790
HI	16.63 (±5.29)	22.63 (±5.85)	0.746
HM	18.50 (±8.69)	24.00 (±6.50)	0.763
HT	18.25 (±5.47)	28.88 (±5.64)	0.640
HIMT	15.38 (±6.21)	22.63 (±6.02)	0.679

The ratio of correct answers to novel information screens seen was calculated. A higher ratio would suggest more effective coverage of the material would produce better learning. From the results in Table 5.3, it can be seen that in the hypertext navigation (H) produced the highest mean whereas the tour (HT) condition produced the lowest. These differences were not significant and our hypotheses that the navigational facilities provided will effect the learning outcome cannot be substantiated.

5.6.2 Directed-task group

The ten-item multiple-choice task booklet was scored for the correct answers. These answers were checked against the log-file data to ensure that answers had been extracted from the correct screens and in the correct sequence. The final test scores were adjusted appropriately by ignoring correct answers to questions where the relevant information screen had not been viewed. The means and standard deviations for the scores in each group are given in Table 5.4. Analysis of variance produced no significant differences. As before, there was no significant difference in the total novel information screens seen by each group.

Table 5.4 Mean scores on the ten-item task booklet and information coverage (directed-task *group)*

Group	Mean score (σ)	Total novel info screens (TNIS) (σ)
H	8.00 (±1.77)	21.13 (±3.94)
HI	8.00 (±1.07)	19.75 (±4.03)
HM	8.25 (±0.89)	22.13 (±7.61)
HT	6.88 (±2.80)	26.00 (±3.38)
HIMT	8.13 (±1.13)	20.25 (±2.31)

In this case looking at the ratio of correct answers to total novel information screens is not appropriate. More efficient use of the system would mean fewer novel information screens seen.

The data from the log-files were re-analysed to include only the interactions leading to the completion of the first nine questions in the questionnaire booklet. This was because Question 10 was different from the other questions in that it could not have been answered by a direct method (i.e., *map* or *index*), but required more of a search strategy. This re-analysis gave new scores for the task, as well as new times for completion, new percentage usage of the facilities and different efficiency measures (see Table 5.5). There was no significant difference in the mean number of correct responses between the groups, nor in the total time taken to complete the task. The HT group did have the highest mean for correct answers and the highest mean for time taken for completion. Significant differences may have been obtained if the groups had been larger since there was large amount of observed variability between subjects. Also, the figures for the time taken to complete are distorted by the *ceiling effect* produced by the twenty minute cut-off. A mean of 19.97 minutes would suggest that the *true* 'time to completion' would have been considerably more for this HT group.

Table 5.5 Results for the first nine questions of directed-task booklet

Group	Mean number correct	σ	Time to complete (mins)	σ	Mean novel info screens	σ
H	7.88	±1.64	19.31	±1.90	18.63	±3.62
HI	7.50	±2.07	17.22	±4.02	17.25	±3.28
HM	8.00	±0.93	17.83	±3.54	17.88	±3.40
HT	6.88	±2.80	19.97	±1.15	25.63	±3.89
HIMT	7.88	±1.25	18.78	±1.97	18.63	±2.33

5.7 Subjective Questionnaire

Immediately following their system usage, subjects completed the five-item questionnaire rating their impressions of the system. For the *exploratory task* group, this was given prior to the 50-item multiple-choice questionnaire so not to influence responses. The five questions were:–

Q1. How easy was the "York Tourist's Guide to use?

Q2. How often did you get lost using the system?

Q3. How much of the available material did you manage to see?

Q4. How successful do you think the system is for learning about York?

Q5. How does it compare with using books for learning?

The subjective questionnaire was analysed by converting the mark on the linear scale into a score between 0 and 100, with '100' rated as favourable (e.g. 'easy to use,' 'never lost,' 'saw all material,' 'successful for learning,' 'better than books'). Table 5.6 shows the results.

Two-way between analysis of variance using SPSS^{X} was used to determine any significant differences due to either the task undertaken or the type of facilities provided. Full analysis of variance tables are provided in Appendix H. A table of the mean ratings obtained is given in Table 5.6.

Interpretation of the results are straightforward as there are no interaction effects for any of the five questions. There are no significant effects of facility on responses to any of the five questions. There was, however, a significant effect of task for the first three questions. Subjects in the exploratory group rate the system more easy to use (Question 1 – $F(1,69) = 23.03$, $MSE=150.22$, $p < 0.001$) than subjects in the directed condition. The exploratory group were less frequently 'lost' when using the system. (Question 2 – $F(1,70) = 17.19$, $MSE = 289.97$, $p < 0.001$). Finally, the exploratory group estimated they had seen a greater percentage of the available material (Question 3 – $F(1,70) = 5.36$, $MSE = 595.2$, $p < 0.05$).

5.7.1 Discussion of results for subjective questionnaire

It was expected that responses to various items in the questionnaire would be task dependent. For example, it is more likely that the system would be rated 'easy to use' and 'easy to navigate', if the task did not require specific navigation and specific information retrieval tasks. It would be expected that 'ease of use' and 'never lost' would score highest for the *exploratory-task* group whereas difficulties may have been encountered for the *directed-task* group. This was found to be the case.

5.7.2 Facility differences

It was expected that subjects would rate the system differently dependent upon the facilities available as well as the tasks undertaken. If, as we accept from our earlier evaluations (Chapter 4), multiple navigational facilities can be employed successfully even by the novice user, and we accept that these navigation facilities do provide the expected functionality, then we might expect the full HIMT conditions to be rated highly on questions relation to "success" and the H condition (hypertext only) to be rated low on "success". If, however, provision of multiple navigation functionality has its hidden costs in terms of cognitive overload, or a mismatch of user's conceptual models of the knowledge base and of the system, then the full system would not rate so highly on these measures of success and ease. In turn this would influence the subjects' appraisal of the system alongside that of a book.

Table 5.6 Means and standard deviations (in brackets) for the subjective questionnaire responses

		Hypertext	Hypertext& Index	Hypertext& Map	Hypertext& Tour	Hypertext Index Map& Tour	Means n=40	n=80
Q1 ?ease	T1 (exp)	88.12 (0.97)	85.27 (9.71)	92.50 (4.67)	91.71 (7.44)	88.14 (8.31)	89.15	
	T2 (dir)	78.26 (10.08)	76.61 (17.40)	76.88 (17.40)	77.77 (15.02)	70.00 (19.19)	75.84	82.58
Q2 ?lost	T1 (exp)	91.70 (9.25)	85.80 (17.30)	90.00 (11.16)	92.68 (11.27)	92.95 (6.46)	91.70	
	T2 (dir)	82.59 (21.85)	82.05 (12.15)	67.59 (17.49)	73.93 (25.32)	68.04 (25.49)	74.84	82.73
Q3 ?%seen	T1 (exp)	75.54 (13.16)	66.52 (27.52)	47.59 (28.74)	84.38 (17.62)	55.45 (23.67)	75.54	
	T2 (dir)	60.63 (23.23)	47.06 (27.54)	58.57 (35.88)	51.07 (20.25)	49.02 (18.14)	53.27	59.58
Q4 ?success	T1 (exp)	58.30 (17.20)	85.09 (10.97)	68.39 (25.35)	79.73 (10.55)	64.59 (17.26)	71.39	
	T2 (dir)	80.27 (20.73)	81.52 (11.53)	81.79 (15.67)	72.86 (18.15)	72.41 (21.81)	77.77	74.62
Q5 ?books	T1 (exp)	62.14 (22.29)	72.59 (27.26)	75.00 (20.90)	70.27 17.83)	66.79 (12.90)	69.36	
	T2 (dir)	89.29 (10.91)	75.09 (17.06)	80.54 (26.08)	65.80 (17.60)	62.68 (30.86)	74.68	72.02

It is important to comment on the mean level of responses for the five questions in the subjective questionnaire. Remember that these were scored on a scale from 0-100 where 100 represents a favourable response. For *ease of use* a combined rating of 82.58 (Q1) clearly indicates that the subjects found the system easy to use. Similarly, a combined rating of 82.73 (Q2) indicates that getting lost proved very little problem and Q4, *How successful is the system for learning about York?*, obtained a favourable rating of 74.62. A rating of 72.02 for Question 5 shows that the system was rated better than a book, taking a measure of 50 to be neutral.

Question 3, which explores perceived coverage of the materials, has little value as a measure on its own. A more interesting analysis is the comparison of the subject's perceived coverage of the material (as given in Question 3) and their actual coverage as shown by the log-file data. Divergence between the estimated and actual coverage would indicate a difficulty in obtaining an overview of the amount of material in the system. This has been commonly reported as a difficulty of hypertext systems (Conklin, 1987). In a recent experiment (Gray, 1990) found that naive users who searched for a number of items in a hypertext system, subsequently over-estimated the size of the database. Her system actually contained 68 information screens but the mean estimate was 219.1 ($\sigma = \pm 325.4$!). We would expect that the hypertext only condition would present most difficulty of provision of an overview, whereas the *map*, with a one-to-one mapping (although there were multiple representations of some of the major links represented on the different screens), or an index, with potentially a one-to-many mapping, would be more indicative of available content*.

The comparison of the actual to estimated percentage of screens viewed is more relevant to the *exploratory-task* condition, since the goal for subjects was to achieve a reasonable coverage of the information. Figure 5.26 shows the divergence for the differing facility conditions. The greatest divergence can be seen to occur in the hypertext only (H) condition as predicted. Subjects in this condition *substantially over-estimate* the amount of the material seen. The other conditions, particularly HT and HIMT, show a close matching of the estimate to the actual percentage of screens viewed. The HI condition does show a slight overestimate, whereas the *map* condition (HM) indicates an underestimate. These finding, though not significant, are in the expected directions. Most interesting is that users of hypertext-only navigation thought that they had seen the most information whereas, in fact, they had seen the least. Analysis of variance of the actual percentages of screens viewed and the perceived percentage coverage revealed a significant divergence ($p < 0.01$) for the hypertext-only condition (see Appendix I).

5.8 Conclusions

This experiment has shown that the subjects do understand the facilities available and do use them in an appropriate task-directed fashion. For example, increased use of tours in the *exploratory-task* condition and increased use of index in the *directed-task* condition. The use of the tour facility was generally shunned by this latter group.

* Depending on the mapping, the index facility might provide an over estimate of contents, but, in this experiment, mapping was close to a one-to-one relationship, and could be expected to reflect a fairly accurate estimate.

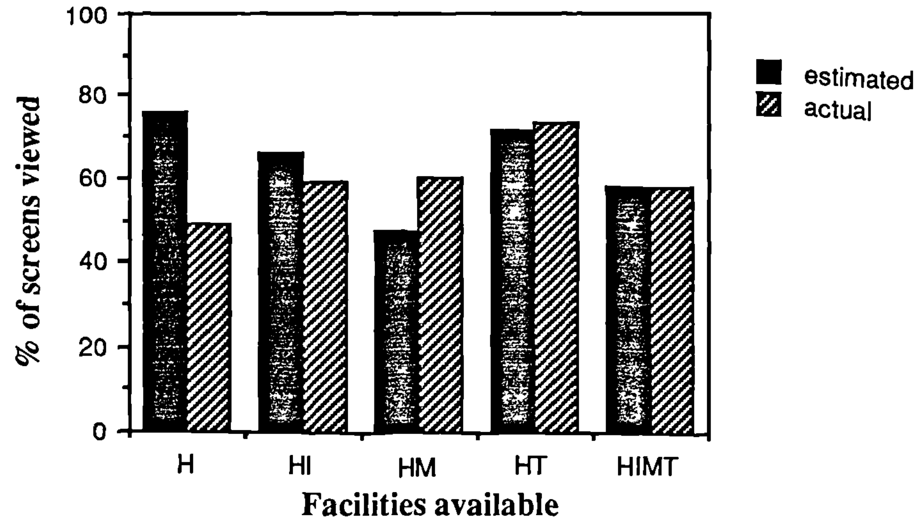

Figure 5.26 Divergence between actual and estimated percentage of screens viewed (Exploratory *condition)*

The expected task differences were best reflected in the full facility (HIMT) condition, suggesting that this multiple provision was not only understood but led to more appropriate system usage.

There does, however, seem to be a trade-off between the perceived ease of use and success of use with task (from subjective questionnaire data). The more focused the task becomes, the more important navigational decisions become. The more directed task leading to lower evaluations of both ease and success. However, this evaluation is based on the first 20 minutes of use of the system by novice users on novel (though conceptually easy) materials. The results may well have been different if a later time slice of system usage had been examined.

Taken as a whole, the system was rated highly for factors relating to its ease of use (ease and orientation) and success (achievement of learning, and considered better than a book). The reason we did not get differing responses for the different facility conditions may be due to the fact that all systems were well rated, and hence these measures were not sensitive enough to differentiate within this narrow spread of responses.

No differentiation between the systems based on the learning outcomes was found. This may have been because of the materials used for the learning or/and the methods used for the evaluation of the learning. This could be accounted for by the total time hypothesis, which states that the amount of learning is directly proportional to the time spent in learning (Baddeley, 1976). This hypothesis only holds for rote learning of relatively unstructured materials (Cooper & Pantle, 1967). The materials used in this study were essentially factual and required little or no organisation. Coupled with the short time available, they would likely have led to a simple rote learning approach by the subjects. Alternatively, multiple-choice questionnaires may not be an adequate vehicle for testing the learning outcomes for anything other than simple factual learning as constructing multiple-choice questionnaires to examine conceptual learning and depth of understanding becomes problematic.

Finally, this study used novice subjects. Patterns of usage may have been different if the subjects had been allowed time to develop strategies with which to approach their learning.

CHAPTER 6

IDENTIFYING STUDENTS' APPROACHES TO LEARNING

6.1 Introduction

The earlier evaluations leave unanswered a number of questions. The main issues that arise are those of the subjects' learning strategies, and how these relate to system usage and learning outcome. Following a summary of the previous work and the evidence for differing learning styles and strategies, the bulk of this Chapter discusses the use of Entwistle's Approaches to Study Inventory as a means of identifying and grouping students for the subsequent experiments. The resulting factor analysis of the results obtained for a sample of 310 University undergraduates is compared with previous work by Entwistle and others. It is intended that this Chapter will introduce the rationale of the experimental testing that will form the subject of Chapter 7.

6.2 Summary of Previous Work

So far we have developed a hypertext presentation system and evaluated its use with undergraduate students on our cognition course over the first two years of system presentation. We have, also, tested novice users (OU students) on novel materials. We have been able to report on the functioning of the interface with some confidence. Our preliminary evaluations (Chapter 4) show that the interface is easy to use and that most of the navigational facilities provided are used by most users. Questionnaire feedback suggested that the students understood the interface and its functionality and were able to report appropriate use of the facilities. Testing, as reported in Chapter 5, has shown that even with novice users these navigational facilities are not only used or reported to be used appropriately but are indeed used appropriately for the tasks undertaken. We have also been able to demonstrate that, generally, use of the system does reflect the typical system usage that was predicted as outlined in Table 6.1.

Table 6.1

Summary table of predicted and observed usage of navigational facilities

Predictions	Findings
tours	
• will be used more by the novice,	used predominantly at the beginning of experimental session.
• or with novel material,	?
• or when browsing.	used most in the browsing or *exploratory task* condition
index	
• will be used when the information required is clearly specified.	found to be the case in the *directed task* condition in the '*York*' experiment.
map	
• will be used both for browsing and directed search, but primarily for the former.	?
hypertext	
• will be used by the *expert user,*	longitudinal analysis shows increased use of hypertext with time.
• or will be used most where the information domain is familiar,	? ?
• or when browsing.	increased use of hypertext in the *exploratory task* condition.
knowing what's there	
• use of facilities (map, index and possibly tours} will increase the user's perception of the scope of the available material.	Provision of maps, index and tours all led to an accurate perception of amount of available material. Use of hypertext only did not.

? – no supporting evidence available

Although typical users can be identified with regard to their longitudinal log file data and the pooled data from users does indeed conform in many respects to the predicted pattern, it is evident that users do exhibit different patterns of system usage even when constrained to particular task-based activities. In the experiment discussed in Chapter 5, not all the variability in user actions can be accounted for by the nature of the task itself. Some of the variability must be inherent to the user.

6.3 Unanswered Questions

- **Do the students' inherent learning styles account for some of the variability in their actions?**

As mentioned above, the task was not found to account for all the variations in system usage. Students could be first grouped dependent on their responses to some form of test of their characteristic learning styles. It would be interesting to know if the differences observed in the log files reflected these characteristic learning styles, if learning style was reflected in learning outcome and if differences in the subjective questionnaire responses were a factor of this grouping.

- **Is early system usage a good measure of usage in *real* learning?**

The previous experiment used novice subjects. This was necessary to show the ease with which the interface could be learnt and used by a population of largely non-computer literate users. Longitudinal analysis from long-term system usage obtained in the preliminary evaluations did show that patterns of usage of the facilities developed over different time spans. If we wish to measure the success of the system, and the appropriateness of its use, it may be better to use subjects further along the learning curve where system functionality has been fully understood and where the use of the available facilities will reflect the users' established navigational strategies.

- **Can we measure learning outcome?**

Another shortcoming of the previous experiments was that they failed to measure the learning outcomes from student exposure to the system. We have not shown that the learning process has been enhanced by the use of this sort of computer-presented knowledge base. Strong claims have been made for the use of hypertext in learning, especially because of the associative nature of a hypertext network and its possible similarity with the way information may be organised, stored and retrieved from human memory. But to date there is little experimental evidence to support these claims. This may be because such *hard* evidence is difficult to acquire. Experiments that have been performed highlight the difficulties of designing such experiments as slight changes to the conditions in a system can have large consequences for the learning outcome (Shneiderman, 1987). There is little point, for instance, in conducting an experiment where a computer-based system is tested alongside a paper version that (for the purpose of designing a controlled experiment) mimics the computer presentation. In reality, the paper version would not be presented in this way. Such an approach would be to disregard the long history and experience gained from the use of the printed medium. Similarly, testing in this way takes only one implementation of a particular computer presentation concept for testing and the detailed implementation of this concept, for example hypertext, may be a crucial factor in its success or usefulness. Therefore, the measurement of true learning may be impossible to perform.

Some of these problems could be addressed by providing a more *difficult* learning exercise, where the material represents a more realistic learning situation, and comparing the students' navigational strategies, and possibly learning outcomes, with certain user characteristics. For this, subjects would be given prior use of the system by way of a practice session, during which familiarity with the interface and its facilities would be acquired. Students would, as detailed below, first be grouped depending on their responses to Entwistle's Attitudes to Study Inventory. It would be more realistic to suppose that we could relate system usage with the user's learning style than to compare such styles with learning outcome. The second objective is fraught with difficulties as meaningful learning may be hard or even impossible to achieve in an experimental situation. The former is the more realistic to achieve although many researchers would dispute the existence of robust learning styles but would argue that they depend upon external factors such as task and motivation. The next Section discusses the existence and nature of robust learning styles.

6.4 Learning Styles and Strategies

CAL systems should be compatible with the student's style of learning. The need to provide a system which allowed for this was detailed in our original list of system requirements. Learning should be seen as an active not a passive process. Perhaps, where feasible, the ideal way to learn is with an environment where learning occurs in the context of doing (Anderson, Farrell and Sauers, 1984). Problem solving techniques are acquired most effectively when there is the opportunity of guided problem solving. However, learners will bring with them widely differing cognitive styles which affect the guidance that should be given.

A cognitive style is a general habitual mode of processing information. Learning styles are simply cognitive styles applied when individuals go about learning. Schmeck (1983) summaries the difference between styles and strategies as follows:–

> "Learning style is a predisposition to adopt a particular learning strategy. A strategy is a pattern of information processing activities which is used to prepare for an anticipated test of memory."

Biggs (1984) considers that a cognitive strategy entails operations and procedures that an individual may use to acquire, retain and retrieve different kinds of knowledge and skills. There is some confusion over the distinction between style and strategy. In a sense, styles are latent and strategies are manifest. Das (1988) discusses this point in some detail. He equates style with Miller, Galenter and Pribaum's (1960) concept of "image" and strategies with plans. Image reflects an individual's totality of knowledge, experience and inclinations; while plans refer to the execution of a group of actions.

> "Both images and plans are responsive to task demands, but at the same time they exist separately from those demands. ... Thus cognitive strategies can go wrong even though the performer has the cognitive style that would facilitate task solution. By the same token, strategies may not reflect style accurately, hence the inferences about a specific style from the measurement of strategies cannot be highly reliable. The two do not correlate perfectly" (Das, 1988).

With this warning in mind, we will briefly describe the nature of identified styles. A variety of cognitive styles has been suggested; for instance Messick et al. (1976) define 19 different dimensions. Though the independent nature of such a variety of cognitive styles has been criticised in that they may simply be differing aspects of a general cognitive ability, they remain useful in exposing the different learning styles which can be applied. These styles must be taken into account by the designer of CAL systems.

Witkin's work (1976) on *field-dependent* and *field-independent* cognitive styles concentrates on the differences in the way an individual structures and analyses information. Pask & Scott (1972) identified *holist* and *serialist* strategies in problem solving – serialist referring to the linear progression from one hypothesis to the next whereas the holist approach is more global. Pask's definitions of serialist and holist, and a category of holist termed a *redundant holist*, have been well elaborated in his later papers (Pask, 1976). Although his early experiments may have accentuated the differences between students, Pask argues that the holist and serialist strategies are the manifestations of underlying differences in the ways people approach learning and problem solving. Students adopt a general tendency to behave in a particular way. Namely, students with consistent learning styles are hence described as *comprehensive learners* (holists) or *operational learners* (serialists), whereas students who are readily able to adapt their approach as appropriate are termed *versatile learners*. Hudson (1968) concentrated on the differences between *convergent* and *divergent* thinking. Kagan et al. (1964) have highlighted another well-known dimension of cognitive style, namely the *reflexive-impulsive* distinction. Though there is evidence that some people consistently demonstrate one form of thinking as opposed to the other, many individuals will change their cognitive style to suit the current task (Webiter & Walker, 1981). Lewis (1976) is critical of much of this work stating that researchers have been "determined to pursue their own pet distinctions in cheerful disregard of one another". What is important in the context of CAL is not whether these distinctions represent true differences in cognitive style but that they are observable.

Certainly, different types of *learning strategies* do exist. Säljö (1979) found that adults with an extended education realised that different types of learning were important for different tasks, whilst unsophisticated learners viewed learning as involving only rote memorization. The awareness that students show about the selection of appropriate strategies is similar to the *cue-consciousness* described by Miller & Parlett (1974) in relation to students' preparation for examinations. For examinations, the careful selection of the materials for study followed by rote learning may be a more successful strategy than the thorough assimilation and integration of a complete body of knowledge. They identify two distinct groups of students. The first group is receptive to, and actively seeks out, cues and hints from their tutors regarding forthcoming examinations. These they term *cue-seeking*. The second group, who are less sophisticated strategists and do not pick up on available hints, are termed *cue-deaf*.

Marton (1988) highlights the difficulties of describing learning outcomes and illuminates the pitfalls of using simple text recall as an operational definition of learning. The most obvious problem is that recall does not necessarily reflect understanding. Marton & Wenestam (1978) examined both quantitative and qualitative differences in the way subjects described the contents of a text (i.e., 1,350-word excerpts from a social studies textbook). In their study, they were able to describe important regularities in both differences with regard to levels of understanding. The text was about social welfare – illustrated by the specific case of a particular family. For one set of subjects this understanding of the text was reported; for a second group, the illustration (i.e., the case of the family) was reported to be the essential subject matter. Thus, two distinctly different meanings of the text as a whole were identified. They conclude that the qualitatively different ways in which certain material is understood correspond to qualitatively different ways in which the material is subjectively organized by the learner. Changes in meaning occur both as a prerequisite to structuring the material and as a consequence of it. Finally, in order to be able to establish a structure – to link the components – the relationships between components need to be seen. Two related aspects of the qualitative differences in the outcome of learning can thus be referred to as meaning (i.e., in the sense of understanding) and structure (i.e., understanding how text is organised). These have become known as the *referential* and the *structural* aspects of outcome.

Based on interview techniques and focusing on the referential aspect of outcome, Marton & Säljö (1976) were able to discriminate students on the basis of their approach to, and process of, reading articles. This distinction was that students adopted either a *deep level of processing* which started with the intention of understanding the meaning of the article and reformulating the arguments with respect to previous knowledge and experience, or a *surface level of processing*, in that it was their intent to memorise the parts of the information that they considered salient, guided by the types of questions they had anticipated. The distinction between *deep* and *surface levels of processing* was replaced in a later paper by *deep* and *surface approaches* (Marton & Säljö, 1984). Svensson (1976) categorised student transcripts derived from learning texts to produce closely coinciding groupings. Concentrating on the structural or organisational aspect, he distinguishes between a *holistic* approach (i.e., integrating the main parts into a structured whole – this is not the same concept as described by Pask) and an *atomistic* approach (i.e., aggregating the parts without integration). These categorisations allowed the relationship of learning outcome to learning style to be investigated.

Svensson (1977) examined the link between a student's approach to learning in an experimental condition and their approach in normal learning conditions. He was able to detect both deep and surface approaches to normal studying and compare these with the examination performance of the student. He found a close relationship between these. The effect of the type of test on the students' approaches to study was investigated by Marton & Säljö (1976). They found that subjects who started with a deep approach often changed to a surface approach on discovery that the questions could always be answered in this way. Subjects with a surface approach, however, were less able to transfer to a deep approach. The Gothenburg research group, led by Marton, repeatedly emphasised the importance of both context and content in affecting the students' approach to learning.

Fransson (1977) examined how levels of interest and anxiety affected students' approaches to learning. His findings were that it was not so much the anxiety-provoking situation that induced a surface approach but that students who felt the situation to be threatening, whether intended or not, were more likely to adopt a surface approach. Lack of interest, or perceived lack of relevance, was also likely to produce this surface approach to the learning.

In a series of experiments conducted by Pask and his colleagues (1972, 1976), the intent was for a deep level of understanding to be reached (unlike the reading of the academic papers in the Marton experiment where instructions to the subjects were in fact vague in order to facilitate the uptake of different strategies). In these experiments he showed that improved learning resulted if the manner of presentation of the learning materials matched the prefered learning stratey of the subject.

This section illustrates something of the diversity of styles and strategies that have been suggested as influences on learning. A problem with all the various classifications that exist are that there are obvious areas of overlap, and that studies have been limited by their task methodology and subject selection.

The work of Entwistle and his colleagues (Entwistle & Ramsden, 1983) was an attempt to obtain evidence for the existence of differing learning styles by studying a wider range of disciplines and to explore the issue of robustness and stability of these characteristics. In particular, the work led to the development of an inventory, based on student interviews, which explored the relationships between the various dimensions of approaches to studying including the inter-relationships between the concepts identified by Marton (*deep* and *surface* processing) and Pask (*holists* and *serialists*). It also included items based on a modified version of the *cue consciousness* ideas of Miller and Parlett, developed into a more general dimension of a *strategic approach to assessment* (Ramsden, 1979). Further items based on motivational factors *(intrinsic/extrinsic)* and *internality* and *openness* were included, influenced by the work of Biggs (1976).

This inventory attempts to draw together the two main components consistently found as predictive of academic success, namely organised study methods and active learning processes (Weinstein & Underwood, 1985), as well as a set of motivational aspects.

6.5 Entwistle's Approaches to Study Inventory

A detailed history of the development of this inventory is provided in Entwistle & Ramsden (1983) and in Entwistle (1988). A five year research programme was initiated in 1976. After a series of pilot studies, during which time the inventory was refined, a national survey was undertaken. The data derived from the use of this inventory came from 2,208 students in 66 departments within British universities and polytechnics, undertaking a mixture of physical science, social science and arts degree courses. All were second year honours undergraduates (third year in Scotland). The final inventory

Table 6.2 Factors and sub-scales of the Approaches to Study Inventory

	Cronbach Alpha
Meaning Orientation	
Deep approach	0.56
Relating ideas	0.47
Use of Evidence	0.38
Intrinsic motivation	0.72
Reproducing Orientation	
Surface approach	0.49
Syllabus-boundness	0.51
Fear of failure	0.45
Extrinsic motivation	0.78
Achieving Orientation	
Strategic approach	0.32
Disorganised study methods	0.71
Negative attitudes to Studying	0.60
Achievement motivation	0.58
Styles and pathologies of learning	
Comprehension learning	0.65
Globetrotting	0.36
Operational learning	0.49
Improvidence	0.42

used in this programme of research contained 64 items covering 16 subscales. A list of the subscales within each of the four domains is given in Table 6.2. The internal consistency reliabilities (denoted by the Cronbach alpha coefficients†) were between 0.78 and 0.32, with a median value of 0.50. Coefficients for the four main domains had a median value of 0.72. Lower values of these coefficients were obtained in a later study by Clarke (1986). He obtained values in the range 0.17 to 0.79. Some of these values are not as high as could be hoped – this is a point that will be returned to later. The final version of the Approaches to Study Inventory questionnaire is given in Appendix J. This was the same questionnaire as used in the current study.

The 16 subscales, together with indices of academic performance at school and in higher education, were included in a principal factor analysis using **SPSS**. Four factors had eigenvalues greater than one and accounted for 55% of the variance. These factors were rotated to oblique simple structure. The factor structure matrix is given in Table 6.3 (taken from Entwistle, 1988; Entwistle & Ramsden, 1983. The 1988 paper interchanged Factors III and IV for no apparent reason).

The four factors that emerged were termed *orientations* to indicate a consistency of approach and also to acknowledge the existence of both approach and motivation as components of three of the factors. The first factor, *Meaning Orientation*, had high loadings on Marton's concept of a Deep Approach to learning and its two associated processes (namely, Relating Ideas and Use of Evidence). Also associated with this factor were Comprehension Learning and Intrinsic Motivation. There were negative loadings for Syllabus-Boundness and Negative Attitudes.

For the second factor, *Reproducing Orientation*, the highest loadings brought together Surface Approach, Operational Learning and Improvidence – all indicating an atomistic way of tackling academic work. The associated motivational subscales were Fear of Failure and Extrinsic Motivation. A negative loading was found for performance in higher education. Entwistle argues that although in theory operational learning is necessary for a versatile deep learning approach, this relationship with surface learning would indicate that students who prefer a serialist strategy may, perhaps through lack of time, adopt a reproductive mode of operation.

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† These coefficients estimate the degree of internal consistency of a questionnaire by comparing the variance of individual items and that of groups of items (Cronbach, 1951).

The remaining two factors were less distinct. The third factor was labelled *Achieving Orientation*. Its highest loadings being Strategic Approach combined with Extrinsic Motivation and Achievement Motivation. Factor four, the least well defined, was specified as *Nonacademic Orientation*, indicating predominantly disorganised study methods and negative attitudes. A negative loading was indicated for Intrinsic Motivation. Entwistle claims that the data provided by the subject interviews indicated a non-academic orientation; that is subjects showing more concern with social or sporting pursuits (presumably accounting for the derivation of the factor name!).

Table 6.3 Factor Structure of the Approaches to Studying Inventory

Approaches to Studying Subscales	Factors[a] I	II	III	IV
School attainment	(-02)	(-13)	(-07)	(-15)
Attainment in higher education[b]	31	-26	(19)	-39
Meaning Orientation				
Deep approach	70			
Relating ideas	65			
Use of Evidence	54			
Intrinsic motivation	72			-25
Reproducing Orientation				
Surface approach		57	30	36
Syllabus-boundness	-41	58		
Fear of failure		50		34
Extrinsic motivation	-25	38	53	
Achieving Orientation				
Strategic approach	29		48	
Disorganised study methods	-25			50
Negative attitudes to Studying	-39			52
Achievement motivation			45	
Learning Style				
Comprehension learning	55			30
Globetrotting				52
Operational learning		62	44	
Improvidence		68	26	

[a]*Decimal points and loadings less than 25% omitted* [b]*Self-rating*

The main aim of the investigation, one of direct relevance to the present study, was to show that relationships between approaches to studying exist. Analysis was able to establish that students do adopt distinctive approaches to studying; the most compelling contrast being between *meaning* and *reproducing orientations*. This approach incorporates many aspects of cognitive styles, but is a rationalisation of these concepts into a broader and more viable learning approach that attempt to overcome some of the criticisms that have been raised earlier concerning cognitive styles.

This Inventory has been used by other research workers (Morgan et al., 1980; Watkins, 1982, 1983; Diaz, 1984). Their results generally confirm the importance of *Meaning* and *Reproducing Orientations* with less general agreement on the remaining two factors. In one analysis Watkins (1982) found that Surface Approach loaded highly on the factor hitherto described as *Nonacademic Orientation*, while there was a separate factor describing an instrumental form of motivation. However, in a subsequent study (Watkins, 1983) derived a three-factor solution and in so doing questioned the existence of the Reproducing Orientation. It can be seen then that exact comparisons are indeed difficult between the different implementations and subsequent analyses of the Inventory, especially where different factor analysis techniques are used. Factors I and II are clearly identified in this study (*ibid*) and are in fairly close agreement with the factors described by Entwistle, but factors III and IV do not show such close agreement. Entwistle claims, however, that close agreement emerges where identical factor analysis methodology is used.

A related inventory – The Inventory of Learning Processes (Schmeck, 1983) – uses the notion of *levels of processing,* developed by Craik & Lockhart (1972), as its underlying framework. This Inventory has consistently revealed four main factors – *deep processing, elaborative processing, fact retention* and *methodical study*. The Approaches to Study Inventory is based on concepts from educational research and from the qualitative analysis of students' own reports of their study practices, substantial agreement has been demonstrated between the factors extracted from this Inventory and from the Inventory of Learning Processes (Entwistle & Waterston, 1988). They were able to show close coincidence between each set of scales to an extent that it may be possible to extract four dimensions – *deep/elaborative, surface, organised* and *strategic/competitive*, which may encompass intention, motivation and distinctive cognitive processes. It should be noted that this last study compared shortened versions of each inventory. The intercorrelations between the two abridged inventories is illustrated, in a condensed form, in Table 6.4.

Table 6.4 Approximate Comparison of Entwistle's and Schmeck's Inventories (Based on product-moment intercorrelations)

Entwistle's Orientations	Schmeck's Learning Processes: Deep Processing	Elaborative Processing	Fact Retention	Methodical Study
Meaning Orientation	+	++	0	++
Reproducing Orientation	--	-	0	0
Achieving Orientation	+-	+-	+-	+-
Nonacademic Orientation	--	0	-	0

Notation:

Very strong positive intercorrelation	++
Strong positive intercorrelation	+
Weak intercorrelation	+-
No intercorrelation	0
Strong negative intercorrelation	-
Very strong negative intercorrelation	--

More support for the validity of an inventory type of approach comes from the work of Biggs (1978, 1987) who, using an independently developed inventory, reported three main factors – *Deep*, *Surface* and *Achieving* (which combines Organisation and Competition). What is important for our current purposes is that these differences appear to be robust – despite their differing theoretical background, individual emphasis and variations in experimental design and analysis. The use of the Approaches to Study Inventory will furnish us with a legitimate means of classifying users into categories that represent clearly differing learning strategies and approaches. Further discussion will be presented after the results of our own investigation are described.

6.6 Relevance to Computer-based Learning

As we can demonstrate through the application of the Approaches to Studying Inventory, students' approaches to learning do differ, and they will manipulate the material to be learnt in different way. Therefore we are able to propose that the actual mechanisms they use will differ. In a conventional learning situation (e.g., learning from reading text) we can have little idea of the true processes utilised by the learner. Do they skim the article first or slowly work from start to finish? Do they exhibit common strategies for gaining an overview (i.e., reading introductions and conclusions)? With computer-based material the techniques involved can be recorded in fine detail as we have a convenient instrument for studying these processes. The flexibility of a hypertext system with opportunities for multiple navigational strategies may well permit and encourage the user to adopt a 'best method' to suit their individual approach.

What we are saying is that the multiple navigational facilities will allow the user the freedom to adopt the best approach for the task or the user. What we cannot claim is that the provision of these tools will necessarily lead to the development of good strategies in the learners (it would be perverse for us to suggest that this would be possible), but the interface and its navigational aids can play a part in affecting appropriate use. Our problem here is with our definition of appropriate, as different students or the same students with increasing familiarity with a particular problem or knowledge domain, or students with differing needs will adopt different learning strategies. Indeed, a single student may exhibit a flexible approach. As has been stated above, we can say little about the learning outcome, both in the sense that hypertext systems offer an improved learning environment over other more traditional environments or in the sense that a particular type of student performs better than another type. Our aims are much more restricted, and hence more realistic. Namely, that we intend to demonstrate that the variability of system usage is to some extent dependent on the user as well as the task. This will be examined, in the next Chapter, in a more realistic learning situation than previous experiments.

6.7 Current Study

6.7.1 Subjects and method

Subjects were members of the York University Subject Panel. These are volunteer students (from a range of Departments) who are recruited during registration for their first academic term. The questionnaires, containing the full Approaches to Study Inventory, were completed during their first term at the University. Subject Panel members receive payment for participation in the experiments but not for questionnaire completion. Subjects included their names, A-level subjects (or equivalents) and current degree course on the questionnaire forms. It was stressed to them that the data would be used solely for scientific purposes and would not be released to any third parties. Completed questionnaires were obtained from 310 students; representing a return rate of 85%. The male:female ratio was 141:169 and the humanities:sciences:mixed:unclassified academic-background ratio was 157:129:20:4. Questionnaires were collected from two consecutive years of subject panel members, hence subjects at the time of the experiments, described in the next Chapter, were a mixture of both first and second year undergraduates.

6.7.2 Factor analysis

The chosen approach to the analysis has not been to emulate that carried out by Entwistle and others in their studies. This was primarily because of the variability of the results obtained. This would suggest a need for the re-analysis of the original inventory questions. Specifically it was believed that the original sub-categorisations should be re-evaluated. Our analysis resulted in a reduced question base as many questions failed to load on any of the four factors, and as some questions were observed to produce bias. It is common in the published literature to provide only the briefest details of the analysis method – usually the results are presented as a *fait accompli*. Here, we will describe some details of the methodology of factor analysis since we wish to compare our findings with those of Entwistle and others. The basic assumptions of factor analysis are that underlying dimensions, or factors, can be used to explain complex phenomena. One goal in analysis is to represent relationships parsimoniously. That is, observed correlations should be explained in as few factors as possible. The second goal is that these factors should be meaningful. Hence a good factor solution is both simple and interpretable.

The analysis by Entwistle (also the case in most other studies using this inventory) combined the raw question responses into their respective totals for each subscale. This distorts the factor analysis in two ways. Firstly, it assumes that all three to six questions in each subscale relate equally to one factor; and secondly, it makes it impossible to remove questions that are biased. Biased questions are those with an 80:20 or greater split for 'yes' or 'no'. Factor analysis techniques, in common with many statistical techniques, assumes approximately normal distributions in sample data. In the analysis presented here, only those questions that would have introduced bias have been removed prior to factor analysis. Eight questions (numbers – 1, 2, 28, 33, 40, 42, 45 and 55) were found to be biased and hence removed prior to further analysis.

The analysis was performed using SPSS^{X} system on the University of York VAX-Cluster. Several different methods exist for estimating the common factors. They differ in the criterion used to define "a good fit". In this analysis, principal axis factoring was used instead of the more usual principal components analysis. The former is an iterative procedure which uses the squared multiple correlation coefficients as the initial estimates

Table 6.5

Factor Analysis – Initial Statistics

FACTOR	EIGENVALUE	PCT OF VAR	CUM PCT
1	5.73559	10.2	10.2
2	3.30915	5.9	16.2
3	2.64810	4.7	20.9
4	2.38468	4.3	25.1
5	2.02022	3.6	28.7
6	1.75023	3.1	31.9
7	1.68435	3.0	34.9
8	1.57290	2.8	37.7
9	1.48351	2.6	40.3
10	1.48010	2.6	43.0
11	1.40862	2.5	45.5
12	1.28876	2.3	47.8
13	1.26599	2.3	50.1
14	1.23396	2.2	52.3
15	1.15550	2.1	54.3
16	1.12542	2.0	56.3
17	1.08905	1.9	58.3
18	1.07424	1.9	60.2
19	1.04716	1.9	62.1
20	1.01572	1.8	63.9
21	.94818	1.7	65.6
22	.93389	1.7	67.2
23	.89102	1.6	68.8
24	.87210	1.6	70.4
25	.86132	1.5	71.9
26	.82038	1.5	73.4
27	.80191	1.4	74.8
28	.75803	1.4	76.2
29	.75245	1.3	77.5
30	.70579	1.3	78.8
31	.69589	1.2	80.0
32	.66752	1.2	81.2
33	.64021	1.1	82.4
34	.63356	1.1	83.5
35	.62224	1.1	84.6
36	.59848	1.1	85.7
37	.57869	1.0	86.7
38	.55903	1.0	87.7
39	.53576	1.0	88.7
40	.51588	.9	89.6
41	.49605	.9	90.5
42	.48590	.9	91.3
43	.46851	.8	92.2
44	.45068	.8	93.0
45	.43269	.8	93.7
46	.40760	.7	94.5
47	.38748	.7	95.2
48	.37903	.7	95.8
49	.36422	.7	96.5
50	.33227	.6	97.1
51	.32367	.6	97.7
52	.29684	.5	98.2
53	.28225	.5	98.7
54	.25869	.5	99.2
55	.23956	.4	99.6
56	.22897	.4	100.0

of the commonalities. The initial number of factors is estimated and the commonalities reestimated. The procedure is repeated until there is a negligible change in the commonality estimates (cf, Norusis, 1985). The initial statistics are shown in Table 6.5.

Several procedures have been proposed for determining the number of factors to use. One criterion suggests that only factors with an eigenvalue greater than unity should be considered. This was the procedure adopted by Entwistle and most other workers, as SPSS provided no other tools at that time. In our case, there are 20 such factors which account for 63.9% of the total variance. This approach does not always lead to a good solution (Norusis, 1985). Recently, Cliff (1988) has shown that this approach is incorrect and will tend to overestimate the true number of factors. Figure 6.1 shows the total variance associated with each factor. This scree plot shows a distinct change in gradient between the first four factors and the remaining factors (i.e., the beginning of the *scree*). Experimental evidence indicates that the *scree* begins at the *k*th factor, where *k* is the true number of factors (Cattell, 1966). As we wish, in part, to emulate the analysis of other workers we will proceed with an analysis based on four factors.

The next stage after fixing the number of factors to be four (in this case) is the rotation phase. Since one of the goals of factor analysis is to identify factors that are substantively meaningful, this phase attempts to transform the initial factor matrix into one that is easier to interpret. The mechanics of the rotation phase is to find a set of axes which *align* with the isolated factors. There are two basic techniques – orthogonal rotation – where the axes are maintained at right angles – and oblique rotation – where the axis directions are set to isolate the effects of each factor. Figure 6.2 attempts to illustrate these points. Orthogonal rotation results in factors that are uncorrelated. This is an attractive property, but allowing for some correlation between factors may simplify the factor pattern matrix. It is unlikely that factors are uncorrelated in a population and even more unlikely for a sample, hence oblique rotation was used. The final factor structure matrix is given in Table 6.6. Most published work on the Approaches to Study Inventory employs oblique rotation; the only exceptions are the studies by Meyer & Parsons (1989) and Richardson (1990). They both employ higher-order factor analysis.

6.7.3 Discussion of *full* questionnaire analysis

The analysis produces four well-formed factors, though Factor 3 is composed of only three question responses. The following sections will discuss the consistency and identification of the factors in the Approaches to Studying Inventory, through the findings of various investigators; so here we will present, in isolation, an interpretation of

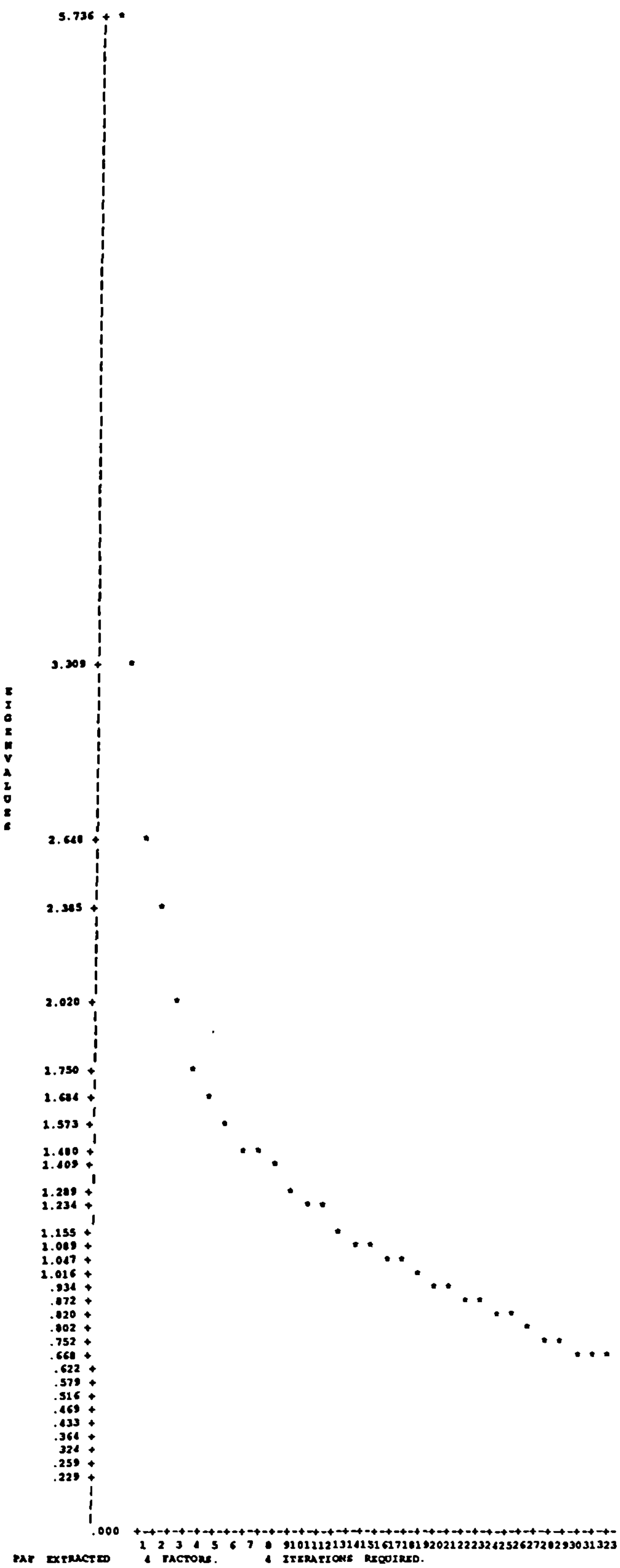


Figure 6.1 Scree diagram

the factor analysis of the uncollapsed questionnaire responses. Factors 1 and 2 are referred to as Meaning and Reproducing approach factors respectively. They are, as we shall demonstrate, comparable with the similarly named factors obtained in the usual analysis.

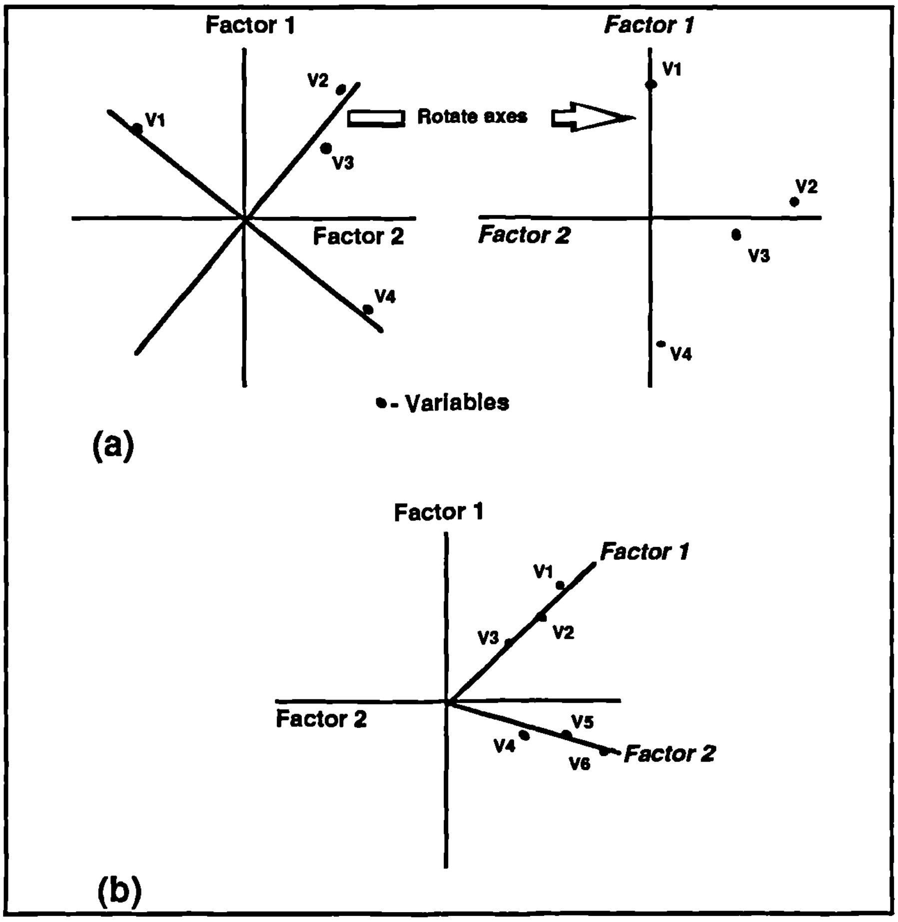


Figure 6.2: Effects of Factor Rotation
(a) Orthgonal rotation
(b) Oblique rotation

Factor 1 Meaning Orientation

Thirteen questions loaded on to this factor (with loadings greater than the arbitrary but generally used cut-off of 0.30). Positive loadings were from the subscales Intrinsic Motivation (4/4)† and Use of Evidence (2/4); and negative loadings were from the subscales Extrinsic Motivation (3/4), Surface Approach (2/6), Syllabus-Boundness (2/3) and Negative Attitude (1/4). Three of these subscales are represented in Ramsden and

† (m/n) refers to m out of n questions in the subscale being represented in this factor.

Entwistle's Factor I, one in their Factor II, one in their Factor IV and the last (Syllabus-Boundness) is represented in both Factors I and II.

Factor 2 Reproducing Orientation

Twelve questions loaded on to this factor – all positive. They were from the subscales Operation Learning (2/3), Surface Approach (3/6), Improvidence (3/4) and Fear of Failure (1/4). All these four subscales contribute to Ramsden and Entwistle's Factor II – Reproducing Orientation.

Factor 3 Introspective Orientation

Only three questions loaded on to this factor – all positive. They were from the subscales Comprehension Learning (2/4) and Globetrotting (1/4). These questions all relate to the subjects' high regard for their introspective thoughts on academic material. The process is essentially concerned with the reorganisation of information and attempting to build coherent descriptions of, and establishing personal meaning for, the material. Such an approach may or may not be successful. Introspection can lead to original insights or to aimless wanderings.

Factor 4 Non-academic Orientation

Seven questions loaded on to this factor. The positive loadings were from the subscales Disorganised Study Methods (4/4), Negative Attitudes (1/4) and Globetrotting (1/4); and the one negative loading was from the subscale Achievement Motivation (1/4). All these subscales, except the negative loading one, are represented in Ramsden and Entwistle's Factor III – Non-academic Orientation.

6.8 Analysis of Collapsed Questionnaire

In order to compare the results of our study with those of other workers, the factor analysis was repeated after collapsing the questionnaire responses into the 16 subscale responses. Section 6.7.2 discussed the reasons why this algebraic summation of raw scores should not be performed. However, it was felt to be a valuable exercise in that it would permit a more direct comparison with the factor analyses performed by other workers. Again, the eight questions that would have introduced bias were removed prior to analysis (it is not certain if such a procedure was employed by other workers). The initial statistics are shown in Table 6.7. Employing the rule that the number of factors is

Table 6.6

Full Questionnaire Factor Analysis – Structure Matrix

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
ANS24	-.54593			
ANS54	-.54526			
ANS51	.53427			
ANS52	.52796			
ANS62	-.52582			
ANS38	-.51712			
ANS08	-.48801			
ANS04	.43141			
ANS64	-.36861			
ANS20	.36697			
ANS36	.32671			
ANS27	-.31196			
ANS03	.31178			
ANS11				
ANS49				
ANS60				
ANS16				
ANS34				
ANS18				
ANS05				
ANS50				
ANS31		.53422		
ANS22		.50393		
ANS53		.44302		
ANS63		.43287		
ANS32		.41009		
ANS06	-.30925	.40297		
ANS15		.40265		
ANS21		.36914		
ANS61		.35955		
ANS37		.34256		
ANS48		.34026		
ANS23		.30567		
ANS39				
ANS19				
ANS25				
ANS47				
ANS13			.51992	
ANS59			.48268	
ANS29			.46032	
ANS07				
ANS30				
ANS58				
ANS17				
ANS43				
ANS46				
ANS44				.49743
ANS56				.49257
ANS10				.48048
ANS26				.40814
ANS57				.40119
ANS14				.38192
ANS12				-.31614
ANS35				
ANS41				
ANS09				

Loadings less than 0.30 are ignored.

determined by the number of eigenvalues greater than unity, this table suggests an analysis based on five factors. However, the scree plot of Figure 6.3 suggests only four factors. Most workers have, like Entwistle, assumed a four factor solution and so we will proceed with a four factor analysis. The final structure matrix is given in Table 6.8.

Table 6.7

Collapsed Questionnaire Factor Analysis – Initial Statistics

FACTOR	EIGENVALUE	PCT OF VAR	CUM PCT
1	3.20145	20.0	20.0
2	1.79395	11.2	31.2
3	1.61785	10.1	41.3
4	1.14394	7.1	48.5
5	1.02122	6.4	54.9
6	.90860	5.7	60.5
7	.80511	5.0	65.6
8	.79282	5.0	70.5
9	.75077	4.7	75.2
10	.71800	4.5	79.7
11	.64714	4.0	83.8
12	.63733	4.0	87.7
13	.56979	3.6	91.3
14	.49833	3.1	94.4
15	.45643	2.9	97.3
16	.43729	2.7	100.0

6.9 Discussion and Comparison of Results

For the purposes of this discussion, we will consider the analyses in the reverse order to that in which they have been presented. This will permit a more logical comparison with the findings from other studies, and follows the chronological sequence of reported work.

6.9.1 Collapsed questionnaire analysis

Table 6.9 compares our results with a representative sample of previously published studies on the Approaches to Studying Inventory. Clearly evident is the consistency of factors 1 and 2. Indeed, they remain identifiable across not only these studies but others (including those employing abbreviated questionnaires) and across a range of students studying in a variety of disciplines, institutions and educational styles. This result gives strong support for the deep-surface dichotomy suggested by Marton & Säljö (1976). In detail, our factor 1 bears closest similarity, in terms of subscale loadings, with those of Watkins (1983). This study employed only a three factor analysis. There are weaker

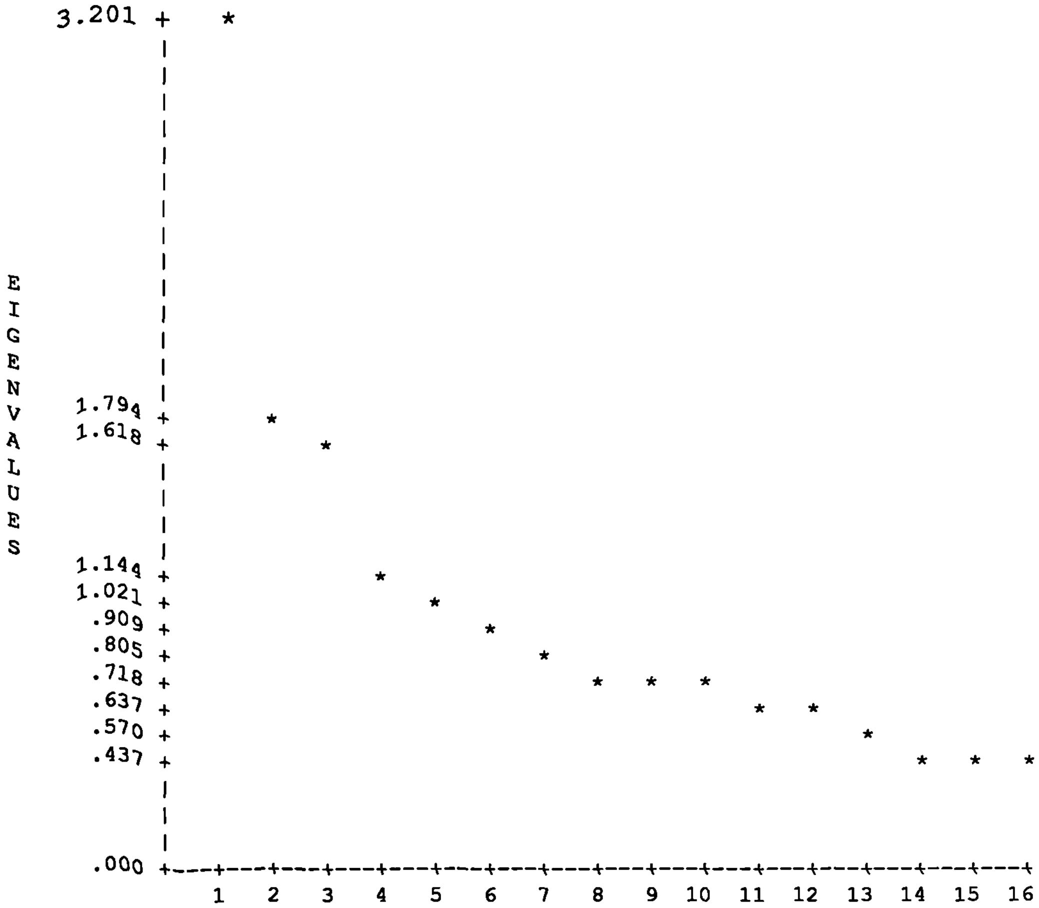


Figure 6.3: Scree Plot for Collapsed Questionnaire Factor Analysis

Table 6.8

Collapsed Questionnaire Factor Analysis – Structure Matrix

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
Intrinsic Motivation	.65373			
Syllabus-Boundness	-.52821	.42378		
Extrinsic Motivation	-.52791			
Negative Attitudes	-.35357		.35026	
Relating Ideas	.33200			
Improvidence		.68765		
Operation Learning		.67363		
Surface Approach	-.39000	.60661	.33118	
Deep Approach	.33334	-.36453		.32339
Disorganised Study			.53327	
Fear of Failure		.38105	.43635	
Globetrotting			.41619	
Comprehension Learning				
Use of Evidence	.37412			.53084
Strategic Approach				
Achievement Motivation				

Loadings less than 0.30 are ignored.

Table 6.9

Comparison of Factor Analysis Results

	1. Meaning Approach							2. Reproducing Approach							3. Non-academic Approach							4. Goal Orientation					
	A2	H&K (II)	R&E	MGT (II)	W1	W2	C	A2	H&K (I)	R&E	MGT	W1	W2	C	A2	H&K	R&E	MGT (IV)	W1	W2	C	A2	H&K	R&E	MGT (III)	W1	C
Deep approach	33	67	70	63	66	69	77	-36					-32									32					
Relating ideas	33	67	65	61	67	63	74																				
Use of evidence	37	66	54		51	48	74						-30							35		53					
Intrinsic motivation	65	56	72	64	70	76	76						-37										-35			-33	
Surface approach	-39					-32		61	63	57	67	64	46	35	33		36		37	43	62		44	30			
Syllabus-boundness	-53		-41		-35	-58	-43	42	35	58	54	35	38			40			30	38	56		32				
Fear of failure								38	64	50	59	61	48	56	44		34										
Extrinsic motivation	-53	50			-38	-47				38													66	53	-43	75	66
Strategic approach														55				35	43	51	32	30		48			
Disorganised study									58		58	57	62	72	53		50	39									
Negative attitude	-35		-39		-42				42		50	54	57	63	35		52						46				
Achievement motivation																				34				45	-63	33	75
Comprehension learning		32	55	58	62	52	59							36		-49	30				-39						
Globetrotting									58		69	59	52	68	42	-32	52										
Operation learning		41						67	32	62	42					52		38	73	64	78			44			
Improvidence								69	63	68	64	53	45	30					42	43	70						

<u>Notation</u>

A2	This study
H&K	Harper and Kember(1986)
R&E	Ramsden and Entwistle(1981)
MGT	Morgan, Gibbs and Taylor(1980)
W1	Watkins(1982)
W2	Watkins(1983)
C	Clarke(1986)
(I), etc.	Factor number if different

Only loadings >= 30% are shown.

loadings in our study for the subscales of Deep Approach, Relating Ideas and Use of Evidence. Our negative loading for the Negative Attitude subscale was obtained by Ramsden & Entwistle (1981) and Watkins (1982). In the majority of studies, this subscale is represented as a positive loading in the Reproducing Orientation factor. However, our second factor does clearly represent the Reproducing Orientation. Five of the seven or so commonly occurring subscales are present in their appropriate strength. With the exception of the negative loading of the Deep Approach subscale, it bears the closest similarity with the findings of Ramsden & Entwistle (1981). Taking into account the variations in the student samples, these consistencies are remarkable. All the comparison studies were undertaken on university students (or equivalent educational level) for a range of courses in the United Kingdom and Australia.

Studies in non-Western countries continue to provide a clear picture of the stability of these first two factors. Diaz (1984) tested a sample of Venezuelan university students with a Spanish version of the Inventory, and obtained a remarkable match for factors 1 and 2 with Entwistle's original analysis. Watkins, Hattie and Astilla (1986) used a shortened form of the Inventory on Filipino students and then employed confirmatory factor analysis to test the relationship between their analysis and that of Entwistle. They conclude that a good fit was obtained. Meyer and Parsons (1989) used the Inventory in South Africa and obtained a similar factor structure to other workers. However, as they admit, the South African educational system has much in common with that of the United Kingdom. Kember & Gow (1990) translated the Inventory into Chinese and presented it to degree-level students at Hong Kong Polytechnic. They were able to identify factor structures for deep and achieving approach, but suggest that a narrow approach appeared to dominate for their sample.

The remaining factors (usually two) have proved much less robust. Factor 3 is described by Entwistle as Nonacademic Orientation, and indicating predominantly poorly organised study methods and negative attitudes towards studying. As can be seen from Table 6.9, there is a poor comparison among the studies represented in this table. All studies but the Ramsden & Entwistle (1981) and our own have a loadings greater than 0.30 for Operation Learning. As a number of studies have significant loadings from Surface Approach, Syllabus-boundness and Strategic Approach, Harper & Kember (1989) suggest that this factor "seems to imply a myopic task-orientated approach". They therefore propose the title "Narrow Orientation"; whilst Watkins (1982) employs the title "Operation Learning". Our own study shows remarkable similarity with the subscale loadings obtained by Ramsden and Entwistle. It is the results from other studies that shakes confidence in this robustness of this factor. It may be that fine differences in educational and cultural background are affecting the loadings for this factor.

Factor 4 was labelled by Entwistle as Achieving Orientation. It has, in the majority of studies, been dominated by consistent loadings for Extrinsic Motivation and Achievement Motivation. Entwistle & Ramsden (1983) considered this orientation as containing the subscales Strategic Approach, Disorganised Study Methods, Negative Attitudes to Study and Achievement Motivation. The results of five of the studies, shown in Table 6.9, do not support this composition. Watkins (1983) employed a three factor solution. Our own analysis demonstrates very strange loadings. The dominant loading is Use of Evidence, with weaker contributions from Deep Approach and Strategic Approach. The last two being at or close to the 0.30 cut-off point. There is, perhaps, little point in discussing at length the significance, if any, of this fourth factor. There has been a trend in later work they employ shortened versions of the original inventory questionnaire and then produce a three factor solution (e.g., Entwistle & Waterston, 1988; Coles, 1985) or to employ more stringent statistical methods. Our intention in analysing the collapsed inventory responses was to relate our own study to earlier ones. The analysis of the uncollapsed responses is, we claim, more statistically valid.

We can not improve on the conclusions of Meyer & Parsons (1989), namely that,

> "The results ... confirm the ability of the Approaches to Studying Inventory to produce meaningful and conceptually consistent results. However, the original groupings of subscales into three or four orientations *universally* (sic) descriptive of characteristic approaches to studying adopted by students in different institutional environments has not been supported. Instead, two orientations are consistently evident: a meaning orientation and a reproducing orientation. This finding is consistent with the results of other studies ... which confirm the presence of *two major study orientations but fail to support the additional two orientations* as defined by Entwistle and Ramsden."

6.9.2 Uncollapsed questionnaire analysis

As far as we are aware, no attempt has previously been made at applying factor analysis to the uncollapsed full Inventory. Richardson (1990) performs such an analysis on a shortened version of the Inventory (i.e., 32 questions). It should be noted that his abbreviated version differs from that of Entwistle (1981). Richardson discusses, at some length, the techniques and pitfalls of factor analysis, a demonstration of the test-retest reliability of his inventory and a series of analyses. His findings are detailed here since there are strong comparisons with our own. His final pattern matrix for a three factor solution to his collapsed inventory responses is given in Table 6.10.

Table 6.10

Factor Structure of Richardson's Inventory

(Collapsed Responses)

	Factors		
Subscales	**I**	**II**	**III**
Meaning Orientation			
Deep approach	54		25
Comprehension learning			68
Relating ideas	47		
Use of evidence	89		
Reproducing Orientation			
Surface approach		58	
Improvidence		70	
Fear of failure		44	
Syllabus-boundness		54	
Test-retest Reliability	63	85	82

Decimal points and loadings less than 25% omitted

He employed principal components analysis and the *Very Simple Structure* criterion (Revelle & Rocklin, 1979) to determine the number of factors – in this case, three. The scree test, however, suggested a four factor solution. The extracted factor matrix was then subjected to oblique rotation. Clearly, factor 1 can be identified with Meaning Orientation, and factor 2 with Reproducing Orientation. Factor 3 was uniquely identified with Comprehension Learning. In Entwistle's original Inventory design (see Table 6.2), Comprehension Learning was a subscale of Learning Styles and Pathologies; however, the majority of studies (see Table 6.9) show it loading on Meaning Orientation. Richardson performed a separate analysis on the uncollapsed abbreviated questionnaire responses and identified eight factors using the *Very Simple Structure* criterion. There was a clear match between the eight factors and the eight subscales. Though some factors loaded onto only one or two questions. He also carried out an analysis on the correlations between these two sets of factors – the collapsed (second-order factors) and the uncollapsed (first-order factors). His results are shown in Table 6.11. Again the unique position of the Comprehension Learning subscale is obvious.

Table 6.11

Factor Matrix Relating First-Order Factors to Second-Order Factors of Richardson's Inventory

First-order factor	Second-order factor I	II	III	Test-retest Reliability
Meaning Orientation				
Deep approach	53			64
Comprehension learning			93	80
Relating ideas	63			69
Use of evidence	68			58
Reproducing Orientation				
Surface approach		48		70
Improvidence		62		61
Fear of failure		50		82
Syllabus-boundness		55		78
Test-retest Reliability	70	85	80	

Decimal points and loadings less than 20% omitted

It is difficult to draw exact parallels with our own analysis, since Richardson employed the shortened form of the Inventory where many of the questions relating to Non-academic Orientation had been omitted. This had been due to the suspected non-reliability of the full Inventory in this area. For example, the subscale Disorganised Study Methods (fully represented in our factor 4) appears in the majority of studies as a loading in the Reproducing Orientation factor – exceptions being Ramsden & Entwistle (1981) and our own study. The work presented here and that of Richardson must also cast doubt on the utility of the Comprehension Learning subscale.

In conclusion, the extensive application of the Approaches to Studying Inventory has demonstrated that it is a valid tool in determining the Meaning Orientation – Reproducing Orientation dimensions of students. Our analysis on the uncollapsed full questionnaire data has, fortunately, confirmed the conclusions by other researchers (who employed only the collapsed data for factor analysis) of this finding. The remaining factors are doubtful in terms of their reliability and consistency. It is recommended that the shortened Inventory could be employed (though this needs further confirmation) and that questions relating to Comprehension Learning omitted. While it is strictly less valid, though more convenient, to perform factor analysis on the collapsed responses, if the intention is to determine the magnitude of the first two factors then our work and that of Richardson would suggest that this more utilitarian approach is satisfactory.

6.10 Selection of Experimental Subjects

Our goal was to select groups of subjects in terms of their positions on the Meaning – Reproducing dimensions (based on their questionnaire responses) and to expose them to the experimental situation outlined in Section 6.3 and fully reported in the next Chapter. As the experiment was quite lengthy (taking over one hour to perform), required fairly close supervision and employed limited computer resources, it was necessary to restrict the number of subjects that could be tested. We are interested in examining the differences between groups of subjects rather than the behaviour of individuals. Subjects who exhibit significantly differing orientations are of particular relevance in examining the variations in the use of computer-based learning environments. Therefore, groups were selected on the basis of possessing *extreme* scores for factors 1 and 2 from the uncollapsed questionnaire analysis. The individual standardised values for factor 1 (Meaning Orientation) ranged from -1.68 to +2.93, with a mean of 0.68, and for factor 2 (Reproducing Orientation) ranged from -2.03 to +2.08, with a mean of 0.10. These values were approximately normally distributed with little skewness. Four groups could have been chosen along the lines illustrated in Figure 6.4(a). This would have resulted in groups exhibiting the following characteristics:–

high meaning – high reproducing
high meaning – low reproducing
low meaning – low reproducing
low meaning – high reproducing

It was not possible to identify sufficient subjects in each of these four groups and still retain a close balance in other factors. However, an alternative which permits us to examine some effects of Meaning and Reproducing Orientations while preserving larger grouping for statistical robustness, is to employ only two groups from the extremes of the (factor 2 - factor 1) locus. This is illustrated in Figure 6.4(b). The result is two distinct groups with the largest differences in the two orientations and not high or low absolute values in either orientation. The selection of the two groups was based on their responses to the two sets of questions which contributed to these two principal factors. As the possible range of these question responses differed, each was converted into a corresponding z-score. The algebraic difference in these two sets of z-scores was used to rank the subjects – called the **group score**. The two groups are, now, characterised as:–

Group 1	High reproducing orientation – Low meaningful orientation
Group 2	Low reproducing orientation – High meaningful orientation

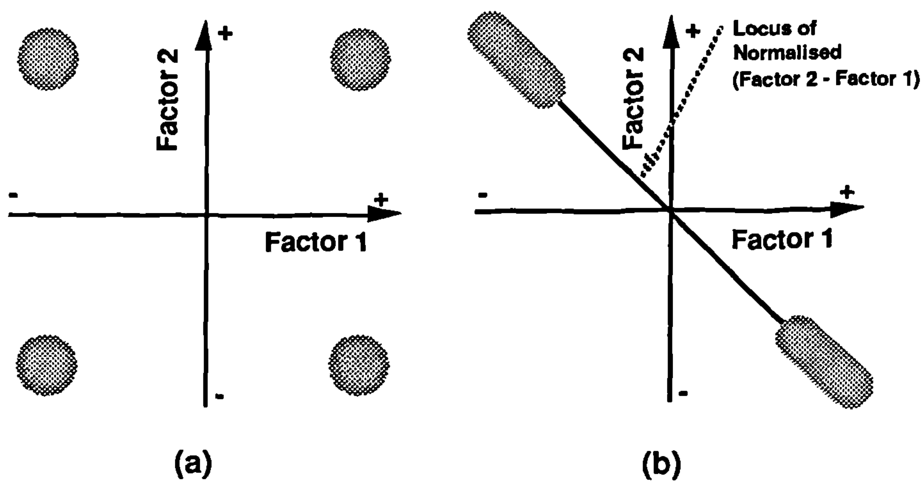
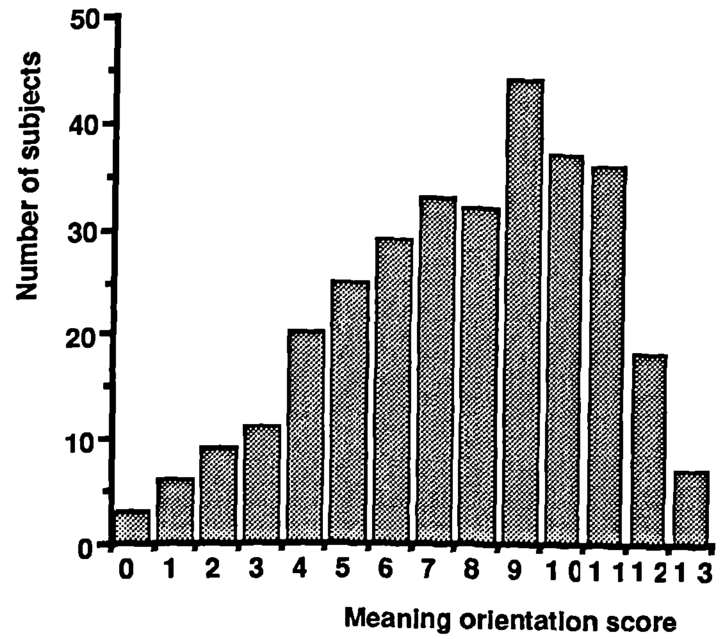


Figure 6.4: Subject Selection

The question responses employed for the two orientations are:–

Meaning Orientation	3, 4, 20, 36, 51, 52, 100 to 106	(13 questions in total)
Reproducing Orientation	6, 15, 21 to 23, 31, 32, 48, 53, 61, 63	(11 questions in total)

The meaning orientation score has a mean of 7.72 ($\sigma = \pm 2.97$) and the reproducing score has a mean of 5.90 ($\sigma = \pm 2.65$) for the full sample of 310 subjects. Histograms of these two scores are shown in Figure 6.5.



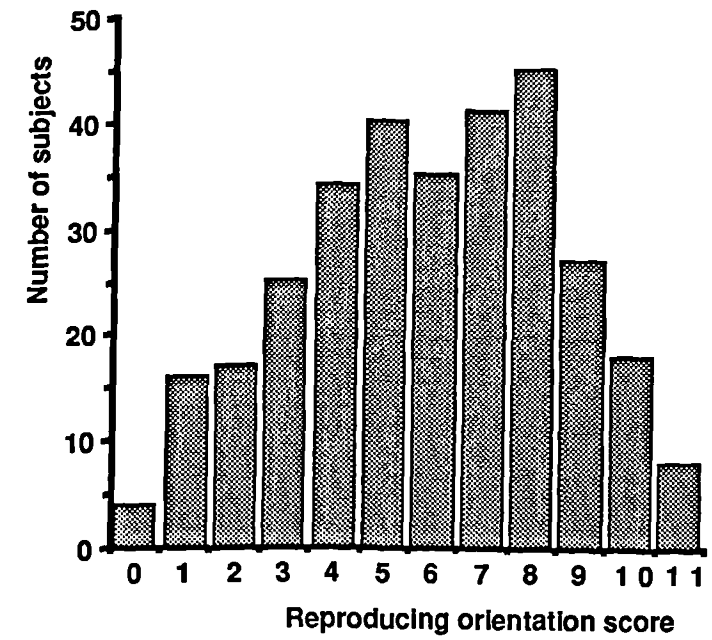


Figure 6.5 Histograms of meaning orientation and reproducing orientation scores for all 310 subjects

The 310 subjects were ranked with respect to their group score (i.e., z-score for reproducing orientation - z-score for meaning orientation). The two subject groups chosen for further investigation were chosen from the extremes of this ranking. This design, however, will not allow the attribution of particular effects to reproducing and meaningful orientations independently. Care was taken to ensure that the two groups were well balanced in terms of male-female and science-arts splits. The disproportionate number of female arts undergraduates reflects the distribution in the original subject pool.

Also, as the main learning material, detailed in the next Chapter, was concerned with physiological subject matter, undergraduates taking a biology or psychology degree, or possessing A-level biology, were omitted. Subjects were asked to attend the experimental session at a set time (they were also asked to confirm their intention to attend). Several students did not respond, and so the two groups of 18 students who were tested are from the first 40 (highest ranking – 3; lowest ranking – 40) and last 47 (highest ranking – 263; lowest ranking – 305) of the group score ranking. The profiles of the two groups employed in the subsequent experiments are given in Table 6.12.

Table 6.12 Scores for the two selected subject groups

	Group Score				Meaning Orientation Score				Reproducing Orientation Score				Male/ Female		Science/ Arts	
	Min.	Max.	Mean	σ	Min.	Max.	Mean	σ	Min.	Max.	Mean	σ	M	F	S	A
Group One	-3.81	-2.04	-2.60	0.61	0	6	3.78	1.83	7	11	9.28	1.18	6	12	7	11
Group Two	1.82	3.29	2.58	0.55	9	13	11.0	1.41	1	4	2.00	0.97	8	10	7	11

6.11 Conclusions

This Chapter has discussed the relevant background to learning styles and strategies, and the reasons for the choice of Entwistle's Approaches to Study Inventory as a discriminating tool for further experiments on subjects' use of our learning support environment. This Inventory has proved itself to be a reliable indicator of the meaningful and reproducing orientations. Our factor analysis on the uncollapsed questionnaire data is thought to be the first attempt for the full Inventory. It confirms the robustness of the above orientations as the two principal factors and confirms the doubts expressed by many workers on the remaining factors originally suggested by Entwistle. Finally, this Chapter presented the selection mechanisms for the two subject groups for the experiments detailed in the next Chapter.

CHAPTER 7

EFFECTS OF APPROACHES TO STUDY ON NAVIGATIONAL STRATEGIES

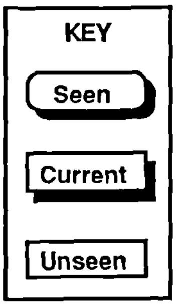
7.1 Introduction

The rationale behind the experiments described in this Chapter are given at the beginning of the previous Chapter. The essential aims were to discover the effects on system usage and learning outcome for two groups of subjects selected for high reproducing/low meaning orientations and low reproducing/high meaning orientations factors from Entwistle's Approaches to Study Inventory. The functionality of Hitch-hiker's Guide was transferred to a **HyperCard**™ environment on a **Macintosh**™ computer system. This was done in order to present the system on a more widely available computing platform, and also to gain experience in producing software in this important environment. A brief introduction to **HyperCard** is given in Appendix K. This Chapter gives details of this new implementation of Hitch-hiker's Guide and a full description of the experimental material and method. The results of the analysis of the subjects' subject questionnaires, note-taking, examination performance and system usage (through log-file analysis) are presented. These results demonstrate the differing interaction strategies as predicted for these two groups.

7.2 Implementation of Hitch-hiker's Guide

All the features present in the original implementation were transferred to the **HyperCard** version with the exceptions of the on-line help, further reading and quiz facilities. A typical card is shown in Figure 7.1. As **HyperCard** can only cope with monochrome screens, then the use of colour to identify hot-spots and to provide footprinting on the map had to be modified. Hot-spots were identified by bold text or simple arrows (⇨) to the next screen.

The footprinting on the map screens was realised using the following notation:–



The following sections describe, in more detail, the implementation of some of the navigational facilities and log-file generation.

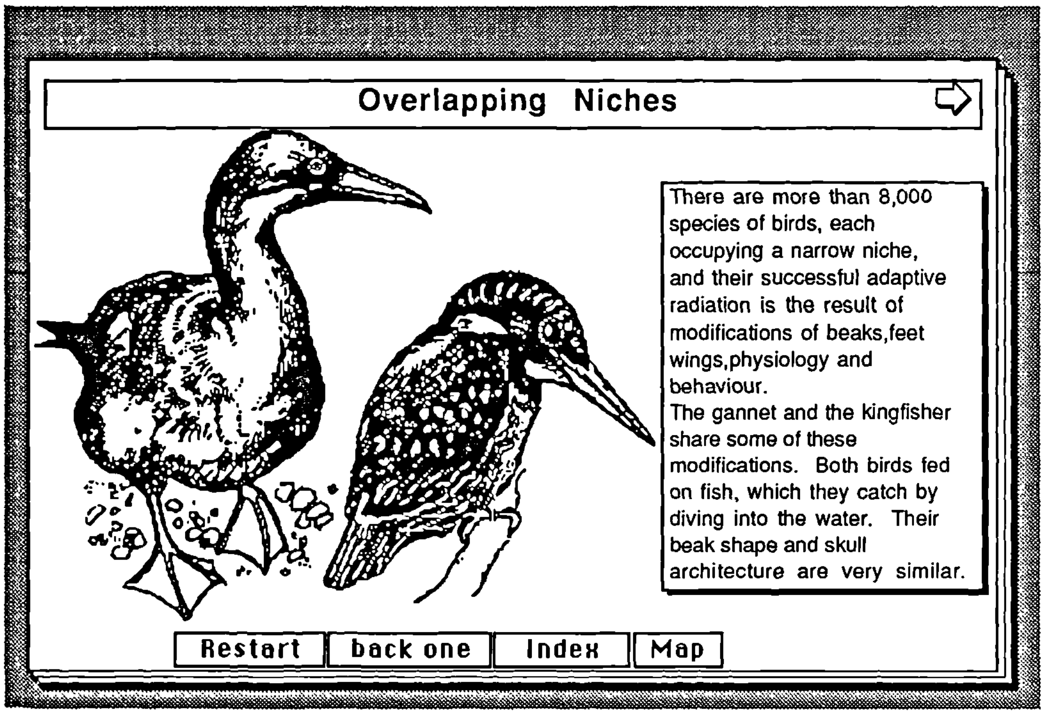


Figure 7.1 Typical Hitch-hiker's Guide card in HyperCard

7.2.1 Card buttons

Each card button possesses a handler of the following form:–

```
on mouseUp
  global tourmode, lastone, tourfile
  if tourmode is two then
    put id of this card into lastone
    put word 3 of lastone into lastone
    put three into tourmode
    close file tourfile
  end if
  go to card id 2948
end mouseUp
```

The basic action is to go to card (in this case) with the identifier `id 2948`. The preceding code is concerned with correctly terminating a tour (if the user is currently on one). The name of the current card is assigned to the global variable `lastone`, so that on re-joining the tour the user will go directly to the last card they saw while on the tour. A similar handler exists for all buttons including background buttons.

7.2.2 'Restart' facility

The bottom line background button, if activated, returns the user to the first card on the stack. Most of this button event handler is concerned with closing down a tour, if the user is currently on a tour (i.e., `tourmode is two`) or has left a tour so that it is dormant (i.e., `tourmode is three`). The global variable `stackcount`, used for the 'back one' facility is also set to zero; this means that the user cannot re-trace their steps after a restart. The global variable `startmode` is used to enable a record of user action to be recorded on the log-file (see Section 7.2.7). The message handler is as following:–

```
on mouseUp
  global tourmode, tourfile, stackcount, startmode
  put 0 into stackcount
  --close down tour if necessary--
  if tourmode is two then
    close file tourfile
    put one into tourmode
    hide background button 5
  end if
  if tourmode is three then
    put one into tourmode
    hide background button 5
  end if
  put true into startmode
  go to first card
end mouseUp
```

7.2.3 'Back one' facility

This bottom-line background button, if activated, permits the user to go back to the previous card. To prevent the user *overshooting* the initial card of the stack and hence displaying the **HyperCard** 'Home Card', it is necessary to maintain a global variable `stackcount`. This variable is initialised to zero on opening the stack or on activating the restart facility, and is incremented by one whenever a card is closed (hence the need to subtract two in the following handler). On closing any cards the following event handler is employed to to create a first-in last-out stack of the user route:–

```
on closecard
  global stackcount
  push this card
  add one to stackcount
end closecard
```

The global variable `prevmode` is used in log-file generation. The following code segment is the event handler for the 'back one' button:–

```
on mouseUp
  global stackcount, prevmode

  if stackcount > 0 then
    subtract 2 from stackcount
    pop card
  end if
  put true into prevmode
end mouseUp
```

Most of this handler is concerned with administering tours (and is omitted in the listing given above).

7.2.4 'Index' facility

This bottom line background button, if activated, permits the user to go directly to an index of all information cards. Each card is accessible from this index by activating the mouse button over the card title. Again a global variable (`indexmode`) is set to true to permit a log-file record of user action.

7.2.5 'Map' facility

A typical map card is illustrated in Figure 7.2. Map cards are accessed by activating the 'map' bottom-line background button on the information cards. The map card displayed is the appropriate one for the part of the information network in which the user is currently working. The background buttons, with the exception of the 'back one' button, are not provided on the map cards. The maps show the logical arrangement of the information cards, and each card is accessible via its labelled button. The map cards, also, provides footprinting as discussed earlier. On opening a stack, all the information card buttons are assigned a plain rectangular outline. On opening any information card in the stack, a message is passed to the appropriate map card which changes the outline of the relevant card button to a rounded, shadowed rectangular outline. When the map button is activated, then the current card button on the map card is changed to a shadowed rectangular outline by the following example code segment:–

```
put "chemical" into thisname
get the style of button "chemical"
if lastcard is thisname then
  set the style of button "chemical" to shadow
else
  if it= "shadow" then
    set the style of button "chemical" to roundrect
  end if
end if
```

This code also causes the outline to revert to the *seen* style on the next access to the map. As with the previous facilities a global variable, called mapmode, is set to true in order to enable a record of user action to be preserved in the user log-file.

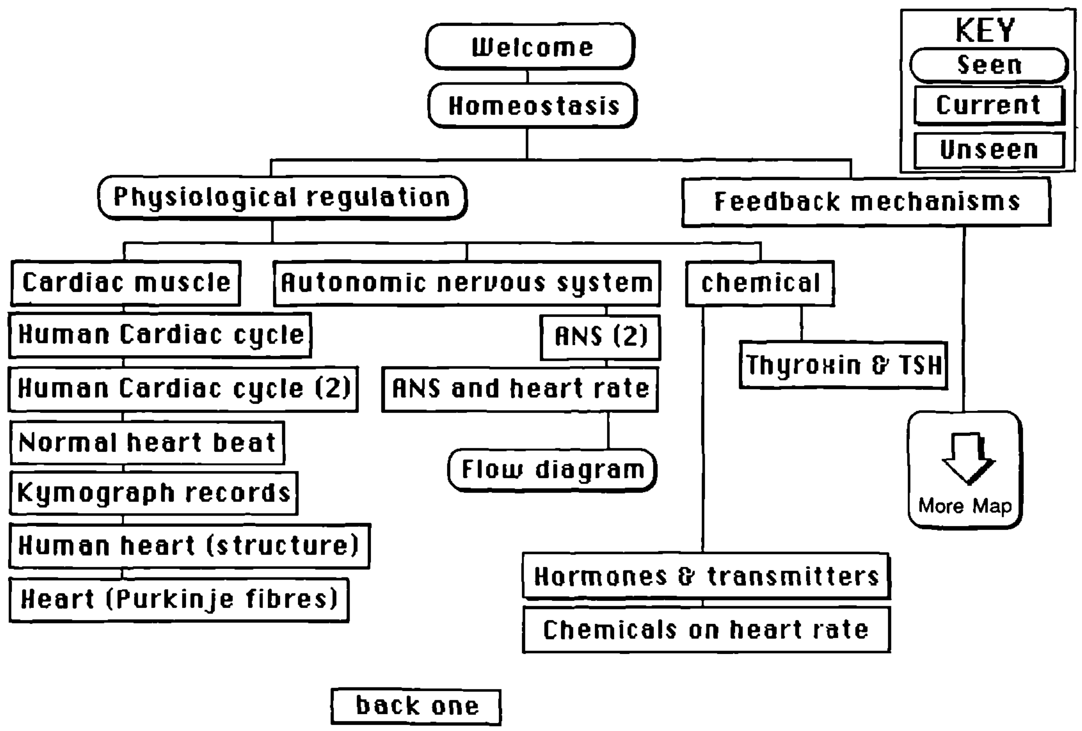


Figure 7.2 Typical Map Card

7.2.6 'Tour' facility

The functionality of tours is the same as that provided in the original version of the Hitch-hiker's Guide; this is illustrated in Figure 7.3. Tours are initiated by activating the bus icon button, the first card on the tour is then displayed and the 'Next' bottom line background button displayed. On activating this button, the next card on the tour is displayed and so on. If the user leaves a tour, by activating any other button on a card (including the bottom line buttons) then the corresponding action is initiated and the 'Next' button is now labelled 'Tour'. On re-joining the tour, that is activating the 'Tour' button, the tour is restarted at the last card of the tour seen by the user. At the end of the

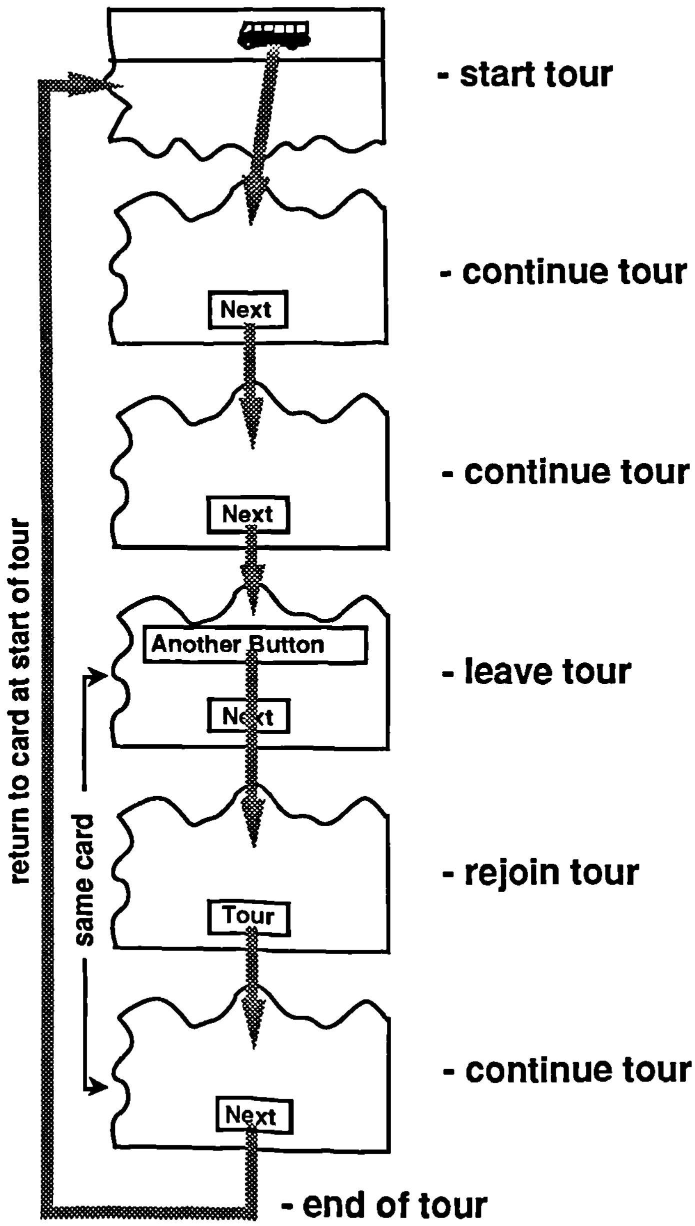


Figure 7.3 Tour Protocol

tour, the user is passed back to the card from which the tour was first initiated. The ability to re-join a tour is lost if the 'Restart' facility is evoked or the user starts another tour.

The tour status is maintained in a global variable `tourmode`; this can be in one of three states, namely:–

Tour status	`tourmode` state
off	1
active	2
dormant	3

The state is initialised to '1' on opening the stack, and can only be set to '2' by activating a bus icon button. If a tour is left before completion, the state is changed to '3'. The following event handler is associated with the bus icon buttons:–

```
on mouseUp
  --start of tour--
  global startcard, tourmode, tourfile
  if tourmode = two then
    close file tourfile
  end if

  put "tourF2" into jim
  put jim into tourfile
  put two into tourmode
  put id of this card into startcard
  open file tourfile
  read from file tourfile until return
  put it into fred
  if fred > 0 then
    go to card id fred
  end if
end mouseUp
```

The sequence of cards for each tour is held in an external text file (in this case called "tourF2"). The event handler on the 'Tour' button needs to perform a number of functions, as illustrated in the following code segment:–

```
on mouseUp
  global startcard, tourmode, lastone, tourfile
  --if on tour do this...--
  if tourmode is two then
    read from file tourfile until return
    put it into fred
    if fred >  0 then
      go to card id fred
    else
      put one into tourmode
      go to startcard
      close file tourfile
    end if
  end if
  --if tour is sleepy, wake it up..--
  if tourmode is three then
    open file tourfile
    repeat forever
      read from file tourfile until return
      put it into fred
      if fred is  lastone or fred <= 0 then exit repeat
    end repeat
    if fred > 0 then
      put id of this card into jim
      put word three of jim into jim
      if jim = lastone then
        read from file tourfile until return
        put it into fred
      end if
      if fred > 0 then
        put two into tourmode
        go to card id fred
      else
        put one into tourmode
        go to startcard
        close file tourfile
      end if

    else
      put one into tourmode
      go to startcard
      close file tourfile
    end if
  end if
end mouseUp
```

This segment needs to handle the cases of active and dormant tours, and return to the card from which the tour was initiated if the end of tour is reached. Every other button in the stack needs to incorporate in its event handler procedures for making a tour dormant and recording the identity of the current card so that tours can be re-joined in the correct manner.

A typical example of such a handler is as follows:–

```
on mouseUp
  global tourmode, lastone, tourfile, indexmode
  if tourmode is two then
    --save details of last card if on tour
    put id of this card into lastone
    put word 3 of lastone into lastone
    put three into tourmode
    close file tourfile
  end if
  put true into indexmode
  go to card id 9132
  pass mouseUp
end mouseUp
```

On opening any card, the status of `tourmode` needs to be checked so that the 'Tour'/'Next' background button can be displayed correctly. Hence the background to each card contains the following handler:–

```
on openCard
  global lastcard, tourmode, lastone

  if tourmode is one then
    hide background button 5
  else
    show background button 5
  end if
  put id of this card into jim

  if tourmode is three then
    if jim = lastone then
      set name of background button 5 to "Next"
    else set name of background button 5 to "Tour"

  else if tourmode is two then
    set name of background button 5 to "Next"
  end if
  put the short name of this card into bkgnd field "title"
  put the short name of this card into lastcard
  pass openCard
end openCard
```

7.2.6 Log-file generation

A typical user log-file segment is given below:–

```
RESULTS FOR FB-log.dummy 30/5/91 9:10 am
*
N      15373 0.010
N      2948  0.081
N      16541 0.112
T      3586  0.193
T      3988  0.284
T      5070  0.365
M      9266  0.446
N      11980 0.477
N      10631 0.558
N      11980 0.627
P      11980 0.665
T      5070  0.698
T      8210  0.729
T      11980 0.751


M      9749  1.518
N      7107  1.549
N      9749  1.683
P      9749  1.690
N      9266  1.696
N      16541 1.720
S      15373 1.761
N      2948  1.832
N      16541 1.863
N      3586  1.894
N      3988  1.925
N      5070  1.966


F      2057  29.684
```

After the header, which identifies the user through the log-file name and the date and time at the start of usage, the three columns record the the navigational mode (N – hypertext link; P – Back one; I – Index; M – Map; S – Restart; T – Tour; F – finish), the card identifier and the elapsed time (in minutes) respectively.

The log-file is created by the script associated with the first card, only when it is first displayed, by the following event handler:–

```
on openCard
  global stackcount, newstart, logfile, length, starttime,
record
  show background field "title"
  if newstart is true then
    put 108000 into length -- time fixed at thirty minutes
    ask "Enter User Identification"
    put it into temp
    put  "FB-log."&temp into logfile
    put false into newstart
    open file logfile
    write "RESULTS FOR "& logfile && the date && the short time¬
    & return to file logfile
    write "*" & return to file logfile
    put the value of the ticks into starttime -- time starts now!
  end if
  send "mouseUp" to card button "Welcome" of card id 9266
  pass openCard
end openCard
```

On opening the stack, the user is asked to enter their personal identifier and the time of the session is set, for the purposes of this experiment, to 30 minutes. At the end of this time, the “End Session” card is displayed and no further interaction is possible. Timings are recorded in steps of one hundreds of a minute; however, it is doubtful if a Macintosh computer running **HyperCard** can record time to this accuracy.

The individual user action is recorded through the following event handler on the stack script (i.e., at the top of the message hierarchy):–

```
on openCard
  global tourmode, length, starttime, logfile, startmode,prevmode,¬
  indexmode, mapmode, stackcount

  put (the value of the ticks - starttime) into temp
  if temp >= length then
    -- exit stack, time up!
    go to card id 2057
  else
    if startmode is true or prevmode is true or indexmode is true¬
    or mapmode is true or tourmode is 2 then
      -- the following statements record current navigational mode
      if startmode is true then
        write "S " to file logfile
        put false into startmode
      end if
      if prevmode is true then
        write "P " to file logfile
        put false into prevmode
      end if
```

```
      if indexmode is true then
        write "I " to file logfile
        put false into indexmode
      end if
      if mapmode is true then
        write "M " to file logfile
        put false into mapmode
      end if
      if tourmode is two then
        write "T " to file logfile
      end if
    else
      write "N " to file logfile
    end if
    -- write card id and elapsed time to log-file
    write word 3 of id of this card && round(temp/36)/100 &¬
    stackcount & return to file logfile
  end if
end openCard
```

7.3 Experimental Materials

7.3.1 HyperCard stacks

Two **HyperCard** stacks were produced. The first, describing the **Evolution of Birds** in Darwinian terms, was designed to be practice material. Previously, the controlled testing had been with novice users with log-files being analysed from the user's first encounter with the system and material. The intention in this investigation was to study established navigation strategies, hence the second stack was the main experimental vehicle. This second set of materials covered information on the **Physiological Feedback Mechanisms in Humans** and represented a demanding and realistic learning task. Previous studies using the 'York' material required purely factual learning. The present material was designed to present both factual content and also elements that required a deeper understanding of the concepts involved. Both information stacks lent themselves well to graphical presentation. Graphical elements were generally scanned images obtained using a hand-held scanning device. The **Evolution of Birds** stack consisted of 32 information, one index and two map screens. The **Physiological Feedback Mechanisms in Humans** stack consisted of 28 information, one index and two map screens. Each stack possessed a welcome card and end session card. Figures 7.4 and 7.5 are screen dumps of each complete stack.

7.3.2 Subjective questionnaire

Following the learning phase, subjects were given a break from the material and in this time were given a short questionnaire to complete (see Appendix N). Five of the questions required selection of a number in the range from '1' to '5', that is 'How easy was the computer system to use?' where '1' represented *very easy* and '5' *very hard.* The sixth question asked the subjects to rank the usefulness of the various navigational facilities. The first five questions were as follows:–

- How easy was the computer system to use?
- How successful do you think the computer was in presenting the material?
- How does learning material in this way compare with learning the same material from a book?
- Did you enjoy using the system?
- How difficult was the material you were asked to learn?

7.3.3 Final examination paper

Subjects were given a five page question sheet consisting of 25 questions (see Appendix L). Answers to all the questions could have been found within the information presented. Questions varied in their presentation so that either they required the subject to phrase a specific answer to a question (in a sentence or two at most) or they required the recall of specific facts (e.g., instructions were to fill in missing words from a sentence or paragraph, or to label a diagram that had been given in the text). There were no trick questions. No questions required answers that were based on but not included in the presented information. An attempt was made, however, to provide a balance between those questions where the answer required only a simple recall of presented facts to those where a correct response might indicate a deeper understanding of the material. Ten questions required some understanding and accounted for 52% of the total marks and fifteen questions were simple recall questions and accounted for the remaining 48% of the total marks. The questions were categorised by four pilot subjects – all with some knowledge of the domain.

7.4 Subjects

The selection of the two subject groups is detailed in Section 6.10. There are 18 subjects per group, with Group 1 characterised by high reproducing – low meaningful orientations, and Group 2 by high meaningful orientation – low reproducing orientations.

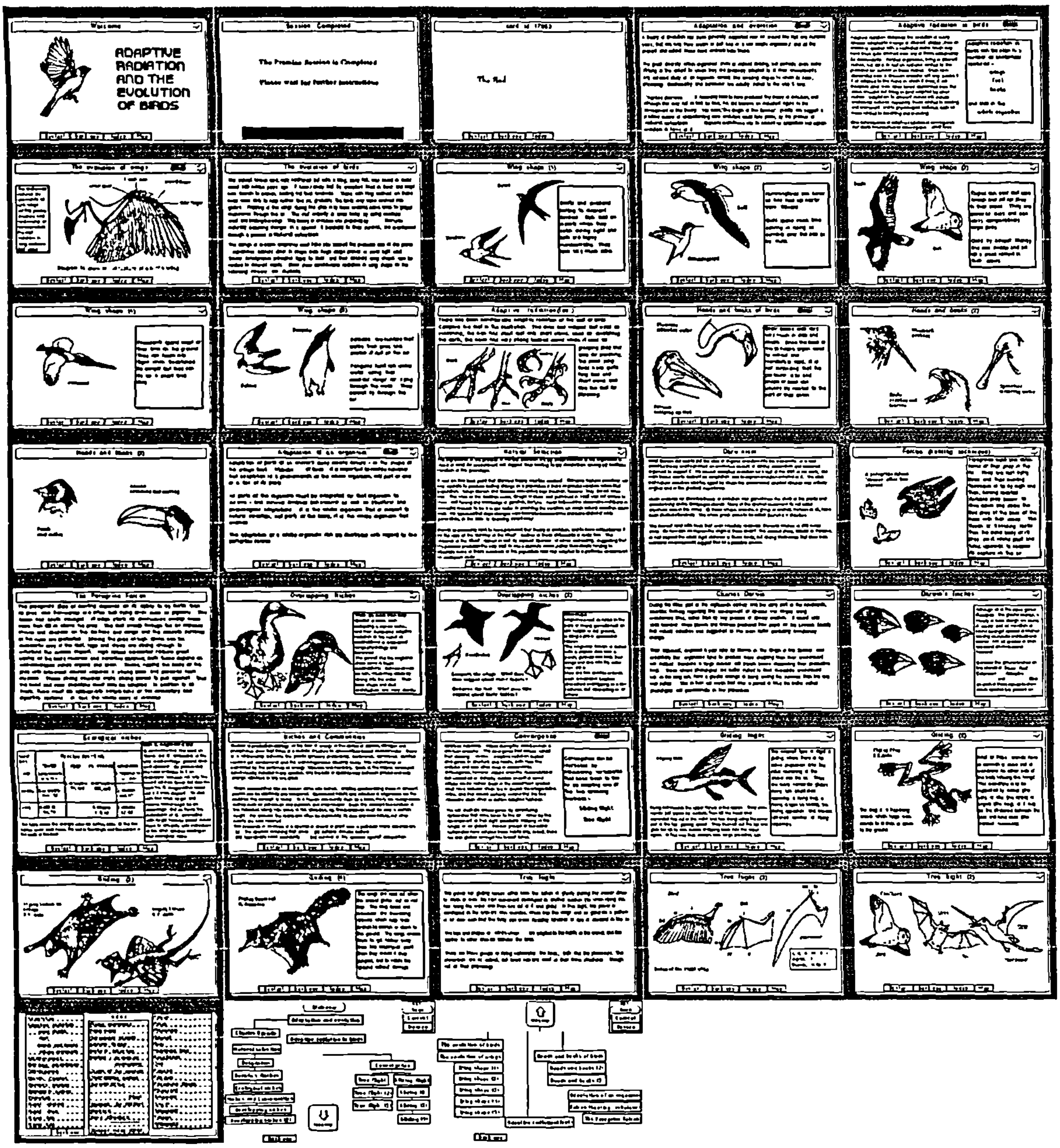


Figure 7.4 *Screen-dump of Evolution of Birds stack*

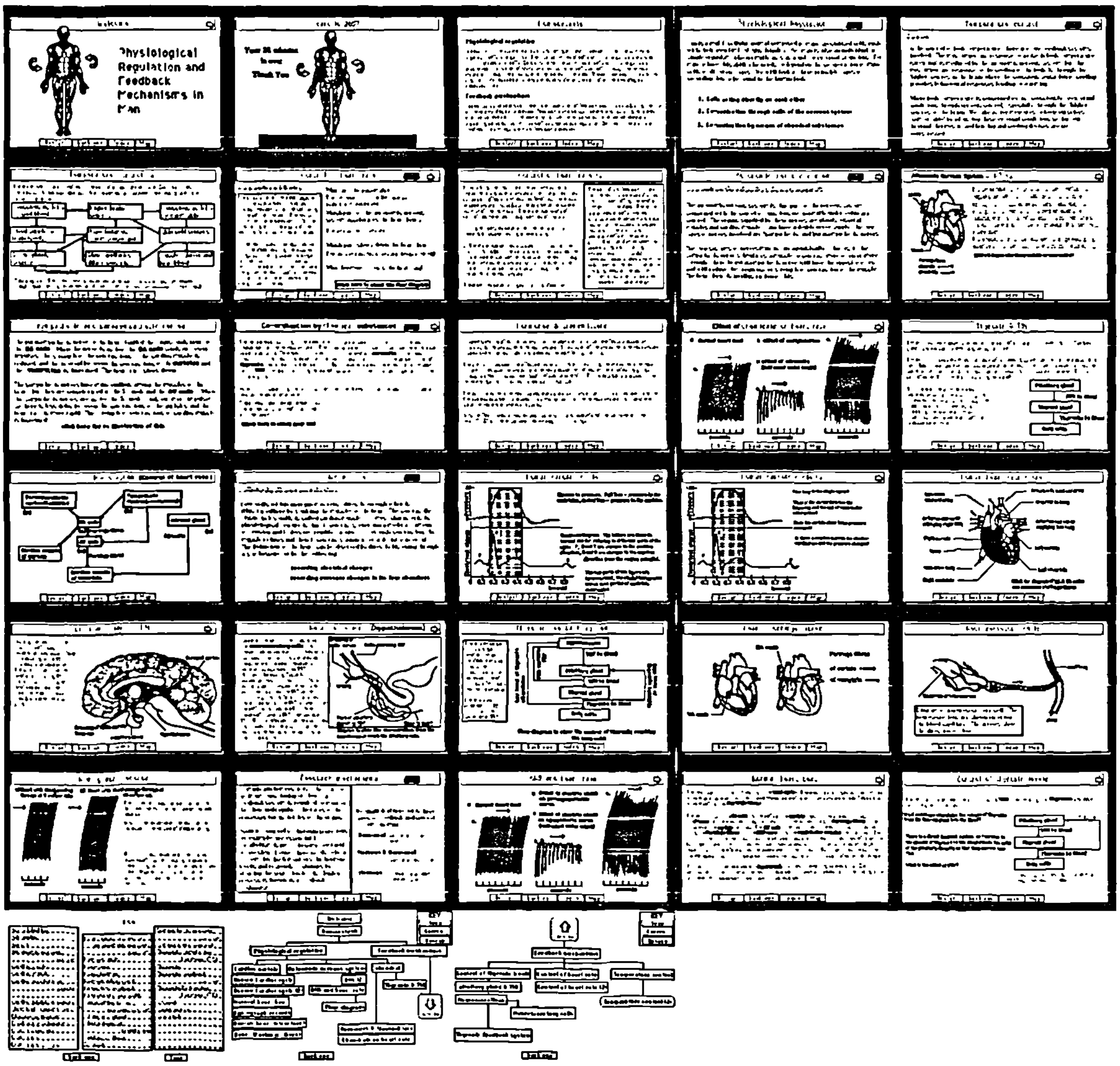


Figure 7.5 Screen-dump of Physiological Feedback Mechanisms in Humans stack

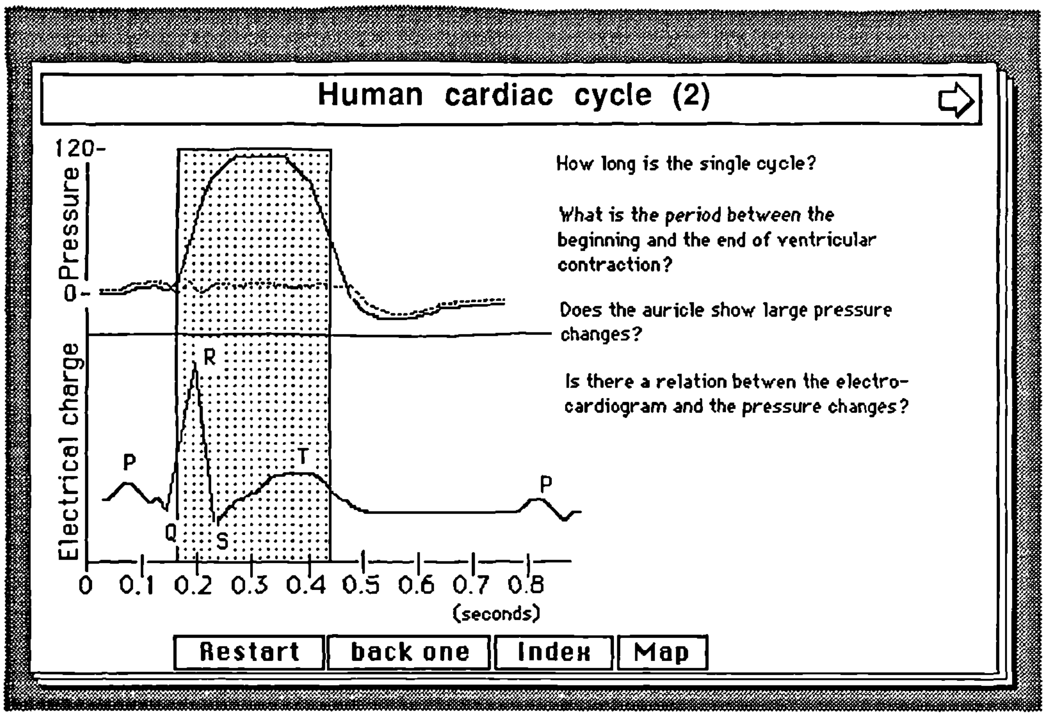
7.5 Method

The experiment consisted of four main sections – a practice computer session, a learning session on the computer, a short break during which time they completed the subjective questionnaire and the final question paper. The total time of the experiment was about one and a half hours, and the subjects worked individually.

7.5.1 Practice phase

The **HyperCard** stack containing information on the **Evolution in Birds** was used to train the users on the available navigational facilities. Subjects were given this practice stack along with some detailed instructions. These instructions can be found in Appendix M. It was, also, stressed that they did not need to learn the information. By following these instructions, the subjects were introduced to the various navigational tools and were given an opportunity to try each one. Through following the instructions precisely they would produce a perfect match between the computer display and the paper documentation, and so provide feedback on the success of their interactions. The final instructions provided were more task-based, for example 'Use the Index to find information on Ecological Niches', or 'Use the Tour to find information on Convergence'. These were included to provide the subjects with an opportunity to explore these facilities for themselves. Subjects were not timed on their practice session and were encouraged to take as long as they needed in order to feel competent with the system before moving on to the learning phase. The average time spent on this session was 15.9 minutes, within a range from 9.5 minutes to 25.1 minutes.

A log-file of user activity was kept for each practice session. As well as providing a record of the time spent on this session, it also familiarised the users with the procedure of entering their name in the initial dialogue box (i.e., the only keyboard entry necessary). This was required for the future identification of the individual subject's log-file. At the end of the practice phase, the subject's attention was drawn to the listing of the navigational facilities given in the instructions of the practice instructions. They were also reminded of the *additional feature* that questions in the text have *hidden answers* and warned that the information to be learnt may contain instances of these. An example of this type of screen is shown in Figure 7.6.



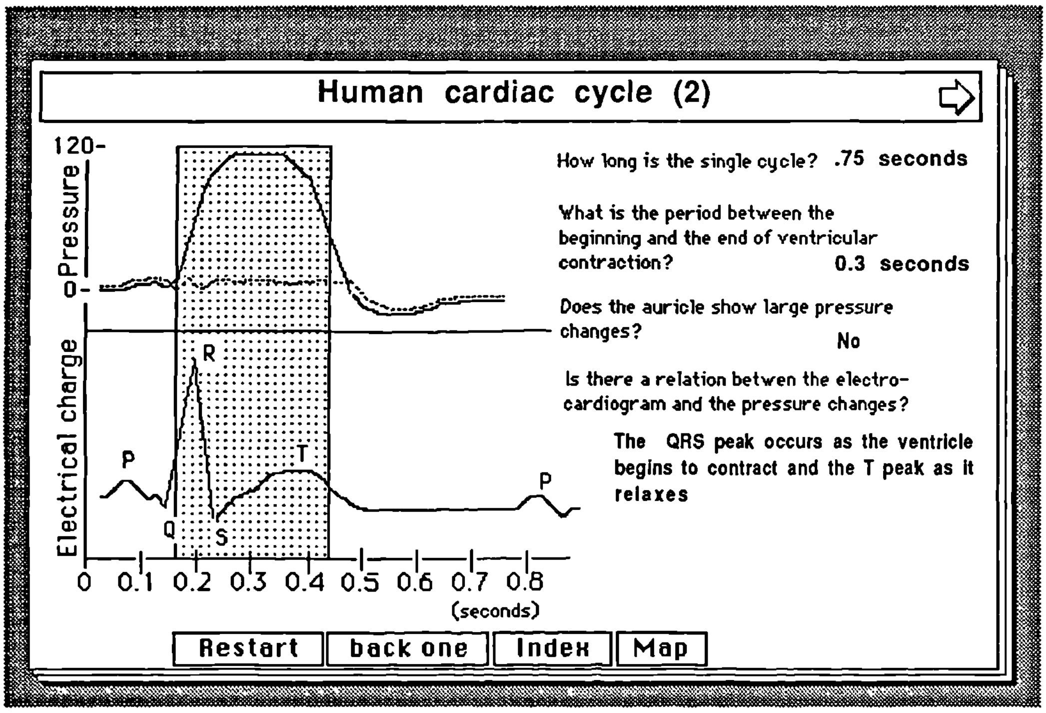


Figure 7.6 Example of embedded questions in card

7.5.2 Learning phase

Immediately following the practice stack, the **HyperCard** stack on **Physiological Feedback Mechanisms in Humans** was loaded onto the computer. Subjects were asked to learn as much of the information as possible in 30 minutes. They were told that the session began as soon as they entered their name into the initial dialogue box and that the computer would inform them when their time was completed. They were encouraged to make notes on paper during this time. It was stressed that these notes were for their own use and that this was an attempt to provide a naturalistic learning situation for conditions where the material to be learnt was challenging. Subjects were told that there would be an opportunity for brief revision using these notes before the examination phase but that they could not be used during the examination itself.

7.5.3 Testing phase

After a short break for revision and completing the subjective questionnaire, subjects were given the five-page question paper to complete. Subjects were given as much time as they required in order to complete this paper.

7.6 Results

The results consist of the subjective questionnaire responses, the notes taken during the learning phase, the examination results and the individual log-files.

7.6.1 Subjective questionnaire

A summary of the results is given in Table 7.1 and more detailed points are discussed below.

- **How easy was the computer system to use?**

As with all previous studies the system was rated easy to use by all subjects. Answers were confined to grades '1' and '2' on a scale from '1' to '5', where '1' represented *very easy* and '5' *very hard*. There were no significant difference between the groups. Hopefully this indicates that all students reached a competent level of system use and understanding, and that system usage did not divert cognitive resources from the learning task.

Table 7.1 *Responses for questions 1 to 4 and 6 of the subjective questionnaire*

	Group 1 High Reproducing	Group 2 High Meaning	Both Groups
Q1 How easy?	$\bar{x}$ = 1.33	$\bar{x}$ = 1.22	$\bar{x}$ = 1.28
	σ = ±0.49	σ = ±0.43	σ = ±0.45
Q2 How successful?	$\bar{x}$ = 2.11	$\bar{x}$ = 2.17	$\bar{x}$ = 2.14
	σ = ±0.68	σ = ±0.71	σ = ±0.68
Q3 How it compare with book?	$\bar{x}$ = 2.00	$\bar{x}$ = 2.56	$\bar{x}$ = 2.28
	σ = ±0.84	σ = ±1.12	σ = ±1.06
Q4 How much enjoyed?	$\bar{x}$ = 2.06	$\bar{x}$ = 2.22	$\bar{x}$ = 2.14
	σ = ±0.87	σ = ±0.81	σ = ±0.83
Q6 How difficult to learn?	$\bar{x}$ = 1.78	$\bar{x}$ = 2.50	$\bar{x}$ = 2.14
	σ = ±0.81	σ = ±0.99	σ = ±0.96

- **How successful do you think the computer was in presenting the material?**

Answers ranged between '1' and '4' on a scale from '1' to '5', where '1' represented *very successful* and '5' *very unsuccessful.* There was no significant difference between the groups.

- **How does learning material in this way compare with learning the same material from a book?**

Answers covered the entire scale range from '1' to '5', where '1' represented *much better* and '5' *much worse.* There was no significant difference between the groups.

- **Did you enjoy using the system?**

Answers ranged from '1' to '4' on a scale from '1' to '5', where '1' represented *very much* and '5' *not at all.* There was no significant difference between the groups.

- **How difficult was the material you were asked to learn?**

Answers ranged from '1' to '4' on a scale from '1' to '5', where '1' represented *very difficult* and '5' *not at all difficult.* There was a significant difference between the groups. The Group 1 (High Reproducing) subjects rated the material more difficult. This result was significant at the 5% level (Independent samples t-test, p = 0.022). As there was no difference in learning outcome as measured by the subsequent examination results, this could imply that Group 1 subjects expended more effort in attempting to learn the material. There was, also, a significant difference between subject groupings (Independent samples t-test, $p = 0.039$) in that science-based subjects found the material easier to learn than the arts-based subjects. This is, of course, not surprising considering the subject matter of the presented information.

Finally, for Question 5, which asked the subjects to rank the navigational facilities in response to the following question,

- **Please rank the features you found most useful in navigating between the computer screens?**

The results indicated that subjects (when taken as a body) showed a clear preference for the map facility (see Table 7.2). Tours were placed second, followed by the bold text/arrows and finally the index facility. Subjects did exhibit a greater variance in Group 2 (High Meaning) over the usefulness of the tour, index and bold text/arrow navigation facilities. This would seem to confirm the later findings from the log-file data as the percentage use of tours and indexes show more variability for this group. The percentage use of maps, however, is very similar for the two groups.

7.6.2 Analysis of subjects' notes

During a small pilot study for this experiment, interesting differences were observed in the notes taken by the pilot subjects. One subject's notes were highly structured and organised. Linkages between the concepts were emphasised by recourse to direction arrows; the overall impression of the notes were that of a large 'diagram' or 'map' of the information space. A second subject chose to write notes that were a series of single, independent sentences – totally void of any overall structuring and diagrams. From these initial observations, it was decided to undertake a simple form of analysis of the subjects' revision notes.

Table 7.2 Summary of results for Question 5: the rank ordering of facilities by their usefulness

	Group 1 High Reproducing	Group 2 High Meaning	Both Groups
Map	$\bar{x} = 1.39$	$\bar{x} = 1.22$	$\bar{x} = 1.31$
	$\sigma = \pm 0.70$	$\sigma = \pm 0.55$	$\sigma = \pm 0.62$
Tour	$\bar{x} = 2.00$	$\bar{x} = 2.72$	$\bar{x} = 2.36$
	$\sigma = \pm 0.69$	$\sigma = \pm 1.07$	$\sigma = \pm 0.96$
Bold text or	$\bar{x} = 2.67$	$\bar{x} = 2.72$	$\bar{x} = 2.69$
hypertext links	$\sigma = \pm 0.69$	$\sigma = \pm 0.83$	$\sigma = \pm 0.75$
Index	$\bar{x} = 3.94$	$\bar{x} = 3.33$	$\bar{x} = 3.64$
	$\sigma = \pm 0.24$	$\sigma = \pm 0.77$	$\sigma = \pm 0.64$

The notes made by the subjects during the 30 minute learning phase were assessed on three separate criteria by four independent judges. The criteria used were quantity of notes, the sequentially/linearity of the notes and the presence of diagrams. Judges were asked to score the notes from 1 to 3 on each of the three categories where 1 represented low quantity, linear or sequential notes, and low usage of diagrams and 3 represented high quantity, structured/non-linear notes, and high usage of diagrams. The judges were given no information regarding the subjects.

There were no significant differences in any of these three criteria between groups, or arts/science background or sex; except that females made more notes than males (Independent samples t-test, pooled variance, $p = 0.006$). Two specimen examples of notes – taken from the extremes – are shown in Figure 7.7. It had been hoped that analysis of these notes would have produced more useful information.

7.6.3 Analysis of examination paper

Scores on the question paper indicated a wide range of correct answers, from an overall score of 18% – 92%, with an average of 57%. The results are summarised in Table 7.3. No significant differences were found between the scores obtained for the different groups. This finding was as expected; indicating that the differences in Attitudes to Study, as isolated by the Entwistle questionnaire, were not simply reflecting general ability level. However, it had been supposed that Group 1, namely the Reproducing Orientation Group would score more highly on those questions requiring simple factual answers, while Group 2, consisting of students with a predominantly Meaning

Orientation to study would score more highly on those questions designed to assess more conceptual learning or understanding.

However there was found to be no significant differences between the two groups on these two components of the test. This was our secondary and weaker hypothesis.

Table 7.3 Results obtained by the two groups in the testing phase

		Group 1 High Reproducing	Group 2 High meaning	Combined
Questions assessing factual retention	average %	52.4	59.9	56.2
	range:	24-86	21-89	
	σ:	±17.4	±19.5	
Questions assessing understanding of concepts	average %	59.1	56.6	57.8
	range:	11-92	6-94	
	σ:	±18.6	±26.4	
Overall Score	average %	55.9	58.3	57.1

As already mentioned in Chapter 6, many difficulties are involved in the study of learning outcomes and these provide numerous reasons why we may have failed to show differences. Firstly, students in the unnatural learning situation of an experiment may not adopt the same strategies for learning that they would undertake in a non-stressful environment with learning material that is purposeful for their own motivations and achievement goals (Fransson, 1977). Secondly, although certain questions required more complex answers that others; subjects, through their note-taking and subsequent revision, were also able to revise and possibly replicate these more complex and apparently more meaningful bodies of information. This may just reflect the subject's own perception and expectation of the most likely material on which they were to be tested. To have assessed real meaningful learning and understanding may have required the subjects to go beyond the given facts and generate their own interpretations and make their own deductions from the materials. It may well not be possible to generate this deep processing of material by the subjects, especially with material specifically chosen to be novel and alien. In this experiment, answers to all the questions were clearly available within the information provided.

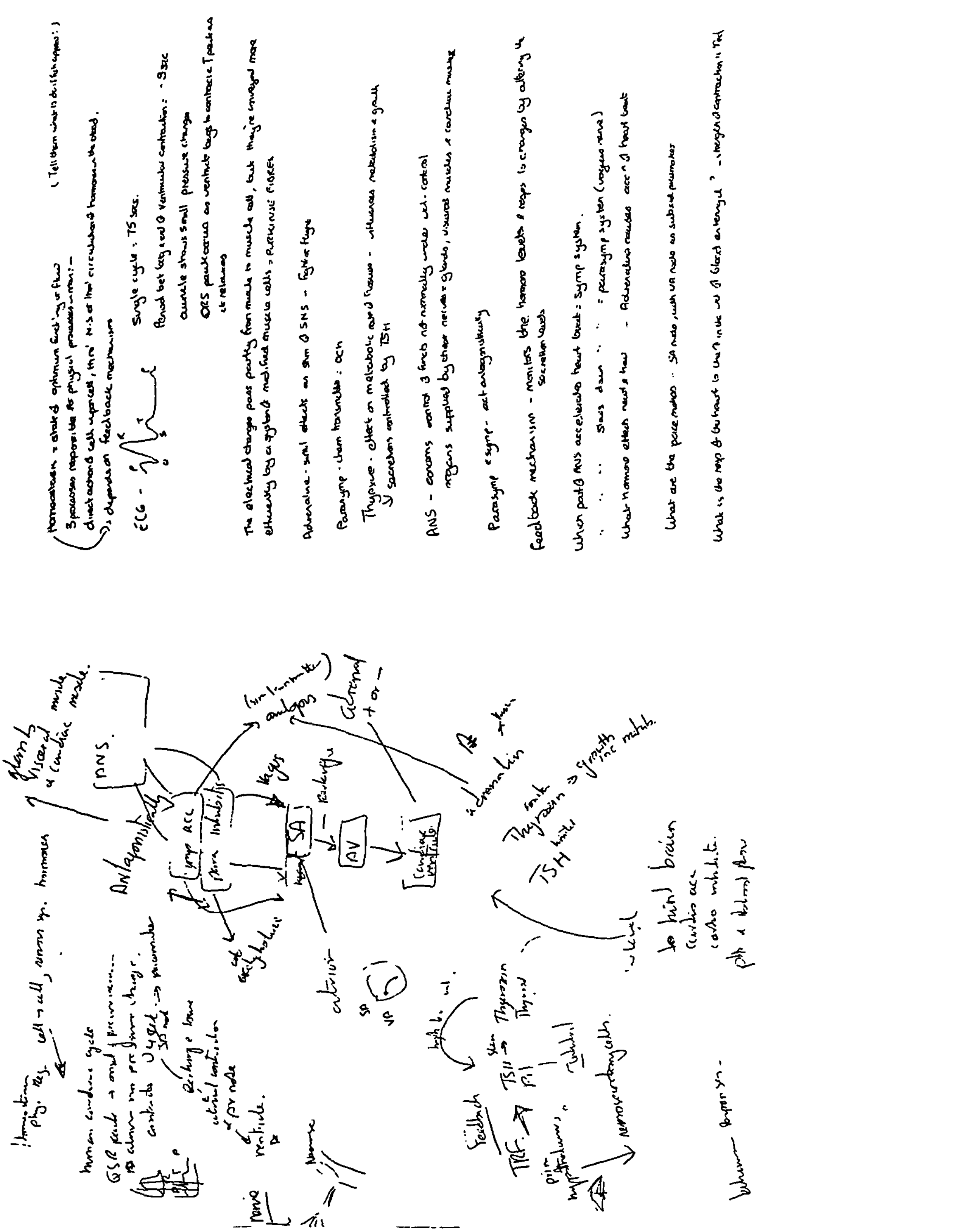


Figure 7.7 Examples of Subjects' Notes

There were no significant differences due to the sex of the subjects. In fact, the only differences discovered were:–

- Science-based students obtained higher marks for the whole question paper when compared with arts-based subjects (ANOVA – $F(1,34) = 5.014$, $MSE = 1665.0$, $p < 0.05$). This is not surprising considering the nature of the learning material. The two groups were well balanced as regards their arts/science mix.

- Students who made greater use of diagrams in their notes performed better at the meaningful questions (ANOVA – $F(1,34) = 6.243$, $MSE = 1458.0$, $p < 0.05$). Taking a median split of diagram use, then *high-diagram* users' mean score on meaningful questions was 65.0 ($\sigma = \pm 18.0$) and for *low-diagram* users, it was 48.8 ($\sigma = \pm 24.9$). There were no significant differences for the scores on reproducing questions. Though further studies would be needed, this improvement in meaningful question scores for *high-diagram* users seems to suggest that the extra effort involved in producing notes in diagram form, which link together various concepts, assists in this type of examination.

The main purpose of the testing session was to produce a realistic learning phase. The scores obtained in this test would indicate that the learning phase had indeed been taken seriously by the vast majority of subjects tested.

7.6.4 Log-file analysis

The system automatically generated a log-file of each subject's navigation throughout the thirty minute interaction with the learning material. From these log-files, it is possible to determine certain features of the interaction; for example, the total number of screens viewed or the percentage of the available screens seen. From this data, efficiency measures of system usage can be determined. The log-files also recorded the type of navigation undertaken in order to traverse from one screen to the next. The log-files could therefore be analysed to determine the percentage of the total interaction that could be accounted for by the various navigation methods. Finally, due to time stamping, the log-file data can be used to determine the patterns of navigation developed during system usage. A log-file analysis program, similar to **LOGSTAT** described in Chapter 5, was written. An example output file is given in Figure 7.8, where each slot is 7.5 minutes in length and the user action codes (e.g., `All`, `N`, `M`, etc.) are equivalent to those described in Chapter 5 and the 'CNS' column denotes the number of consolidated novel information screens. Efficiency is defined as:–

$$\text{Efficiency} = \frac{\text{total number of information screens seen}}{\text{available information screens}} \times 100\%$$

The following three Sections detail the results found from the analysis of these log-files.

```
Results for Student  jbl

 Slot    N      M       I       T       P       S      CNS
   1     7      1       1      11       3       0      13
   2     8      4       0      10       1       0      25
   3    19      6       0       2       6       0      28
   4     6      3       0      15       0       0      28

Consolidated Results
 Type    Nos     Percent    Average time (mins)
All      103      100     0.29
N         40       38.8   0.23
M         14       13.6   0.08
I          1        0.1   0.09
T         38       36.9   0.48
P         10        9.7   0.14
S          0        0     0
BLB       25       24.3   0.10

Total information screens =        85
Total novel information screens =  28
Efficiency (%) =                   41.7
```

Figure 7.8 Typical Output of Log-file Analysis Program

7.6.5 Navigation strategy

Similar analysis techniques as employed in Chapter 5 were used, namely one-way analysis of variance (full analyses are given in Appendix O). A significant difference was found in the total number of screens viewed by the two groups, subjects in Group 1 (high reproducing) seeing significantly fewer screens ($F(1,34) = 5.144$, $MSE = 2095.9$, $p < 0.05$). Despite there being a significant difference between groups with regard to the total screens viewed, there is no significant difference between the two groups with regard to the percentage of the available information screens seen (Group 1 – $\underline{x} = 77\%$; $\sigma = \pm 19.56\%$: Group 2 – $\underline{x} = 86\%$; $\sigma = \pm 12.59\%$). This seems to imply that Group 2 (high meaning) traversed about the screens more in an attempt to elicit the information.

From an interface perspective, efficient usage of the system can be thought to occur when the available information is viewed with the fewest possible interactions (i.e., mouse selections), which would result in the fewest screens being re-viewed. Efficiency in a hypertext system is usually increased by the provision of guidance and access tools. Pure hypertext systems necessitate the repetition of screens by promoting a predominantly trial and error approach to navigation combined with simple navigational strategies such as back-tracking (i.e., the only approach available to elaborate structure from the materials). If we measure efficiency as available information screens as a percentage of total information screen seen, a significant difference between the groups exists ($F(1,34) = 8.681$, $MSE = 119.44$, $p < 0.01$). Group 1 (high reproducing) subjects showing greater efficiency (for detailed findings, see Table 7.4). However, it is not at all clear what the efficiency indices of learning should be. Interface designers have long based their design on information processing theory and not on the individual differences of approach or indeed learning theory (Coventry, 1990). The repeated presentation of the information may help the student structure and assimilate the information. We have no evidence to support such a claim except rather tenuously as there is no evidence to suggest that this *inefficiency* effects the learning outcome as there are no significant differences between the groups on measures of learning outcome.

Table 7.4 Efficiency of coverage of the material

	Group 1	Group 2
Minimum*	12.3	12.6
Maximum*	61.3	45.8
Mean ($\underline{x}$)	40.8	30.1
Std. Dev. (σ)	12.5	9.1

**efficiency measure – available information screens as a percentage of total information screens viewed.*

There was interestingly a difference in this efficiency measure as a function of the subject's sex. Females scored a mean measure of 38.8 ($\sigma = \pm 11.7$) and males scored a mean of 30.2 ($\sigma = \pm 11.0$) (Independent samples t-test, pooled variance, $p = 0.03$).

7.6.6 Navigation methods

From an analysis of the percentage of interactions using specific navigational facilities, a graph of facility usage was generated (see Figure 7.9). Values for tours, indexes and maps give a clear estimate of the actual usage of these facilities as this represents the percentage of tour, index and map screens visited (analysis of the log data shows that the measure of map or index screens seen show a clear correspondence with actual selection from map or index screens). Percentage use of tours at first appears higher than the percentage use of maps, despite maps being the most useful facility according to the subjective questionnaires. At a closer look this is not in conflict with the findings as the screens that can be visited *on a tour* far outnumber the available map screens (of which there are only two). The values in the order of 19% obtained for map usage is encouraging, as is the consistency of map usage both within and between the two groups. No significant difference was found between the two groups with respect to map usage. Our previous studies have reported rather low levels of map usage, which seemed not to reflect their potential usefulness. One could conclude from the present study that map usage was greater on this occasion for one of two reasons, either the map facility was better understood and practised prior to the learning phase or secondly that the learning phase in this experiment represented a more realistic learning task for which the map was seen to be a more useful facility. The fourth category, the bold text/arrow (hypertext links), represents the total number of screens viewed by these two sorts of navigation and can be classified as normal hypertext navigation.

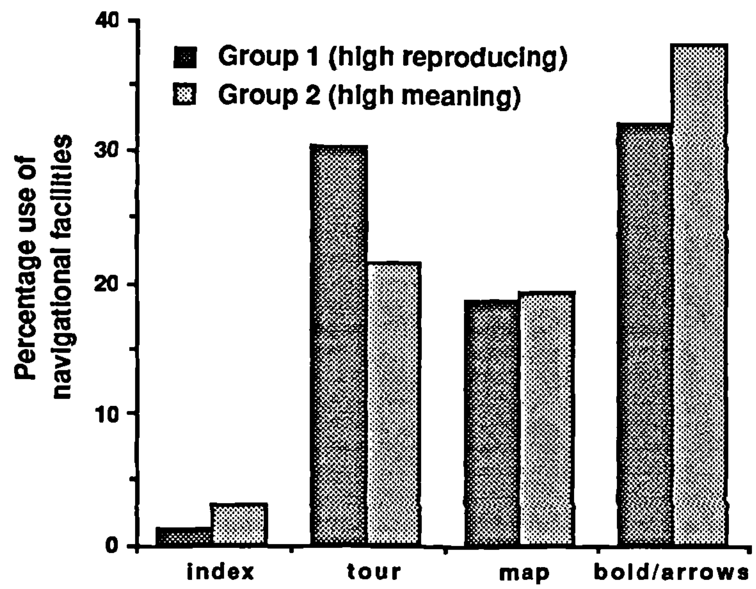


Figure 7.9 Percentage usage of facilities shown by the two subject groups

Significant differences were found for the extent of usage of both tours and indexes between the two groups. Group 1 (high reproducing) showed significantly greater use of the tour ($F(1,34) = 4.526$, $MSE = 123.7$, $p < 0.05$); whilst Group 2 (high meaning) showed significantly greater index usage ($F(1,34) = 4.275$, $MSE = 5.1$, $p < 0.05$). The percentage use of index for the two groups is, however, very low and hence this analysis may not be valid. Nevertheless, it appears that subjects in Group 1 do conform to the expected pattern, that is showing a preference for a linear and structured presentation of the materials. Subjects in Group 2 indicate a tendency to utilise the other less well structured forms of navigation – the index and hypertext navigation (bold text and embedded arrows). The differences between the groups for these types of navigation are not significant; for hypertext navigation (F(1,34) = 3.415, MSE = 53.4, p = 0.07).

7.6.7 Longitudinal analysis of log-files

Using the log-file analysis program, mentioned in Section 7.6.4, the following tables of data were generated. Table 7.5 shows the total interactions occurring within the four 7.5 minute slots of user activity, and Table 7.6 shows the mean number of interactions of each navigational type which occurred in each of four time slots.

Table 7.5 Total interactions for each of four successive time intervals

	slot 1	slot 2	slot 3	slot 4
Group 1 (reproducing)	18.2	18.6	21.1	21.0
Group 2 (meaning)	20.0	32.0	33.5	32.5

From the data in Table 7.5, it can be seen that the initial number of interactions (i.e., the first 7.5 minutes) are the same for both groups. However, Group 2 (high meaning) subjects show a consistently increased rate of activity over Group 1 (high reproducing) subjects for each of the subsequent time slots.

Table 7.6 Navigational activity for each of four time intervals

	Group 1 (high reproducing)				Group 2 (high meaning)			
	slot 1	slot 2	slot 3	slot 4	slot 1	slot 2	slot 3	slot 4
Next	7.8	7.72	8.72	8.5	0.33	14.5	15.83	15.5
Map	3.3	1.94	2.56	4.39	3.28	4.0	5.22	6.5
Index	0.67	0.056	0.056	0.056	0.39	0.72	0.83	1.39
Tour	3.2	5.06	6.5	5.67	3.17	7.056	6.61	5.17
Previous	3.1	3.78	3.22	2.44	2.78	5.5	4.89	3.78
Restart	0.2	0.0	0.0	0.0	0.056	0.22	0.11	0.167

Figure 7.9 shows the use of the individual navigational facilities for the two groups. For all facilities (map, index, back-one, tours, hypertext selection) Group 2 (high meaning) students demonstrate a faster uptake of usage. This is shown by the steeper curve for

each of these facilities between slots 1 and 2. After 15 minutes, the graphs show a parallel relationship for map usage and back-one usage; reflecting the different overall interactions of each group. Note that significant differences were not found for percentage usage of these facilities between the two groups. However, the graphs show that the expected parallel pattern of usage for tours and index does not occur; usage by the two groups is equivalent at 22.5 minutes and, in fact, a cross-over occurs at 30 minutes. This reflects the significant difference that was found for tour usage between the two groups. The incidences of index usage are small, and hence we disregarded significant differences obtained from the statistical analysis. However, it is interesting to note that following an initial inspection at the start of the session, no student in Group 1 (high reproducing) used the index facility during the remaining 75% of the session.

Finally, one other interesting feature of this longitudinal analysis of log-files is the ability to observe trends. In Chapter 5, we were able to claim that a typical pattern of usage developed over time reflecting the *novice* status of the user. In this study we are hopefully examining the interaction of more experienced users, which accounts for the more rapid facility uptake and levels of usage. However, usage of some facilities appears to be tailing off. The reduction in the use of tours (for both groups) in the final time slot might indicate that the tours had all been completed by this stage (i.e. reflecting facility usages dependence on the actual size and content of the hypertext). The most interesting feature however, is the increasing uptake of the map facility with time. Here, we have evidence that the map is being increasingly used as an aid not only to navigation but as a learning tool.

A further interesting trend is illustrated in Figure 7.10. Here, the consolidated novel information screens per time slot is plotted for both groups. Group 2 (high meaning) saw 40% more screens than Group 1 (high reproducing) during the first time slot, but thereafter the rate of seeing new information screens was essentially constant over the remaining time for both groups (Group 1: 5.48 new screens/slot, $r = 0.999$; Group 2: 5.62 new screens/slot, $r = 0.987$).

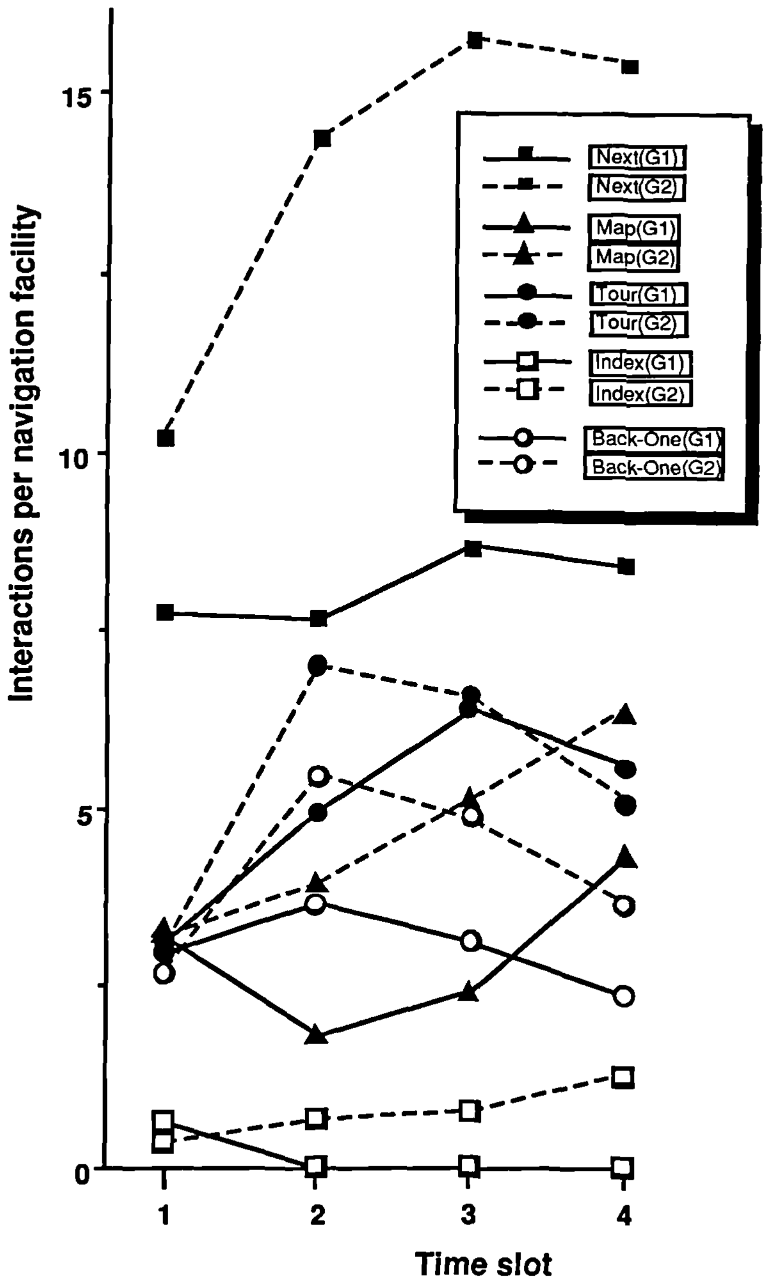


Figure 7.9 Use of navigational facilities over the four successive time slots

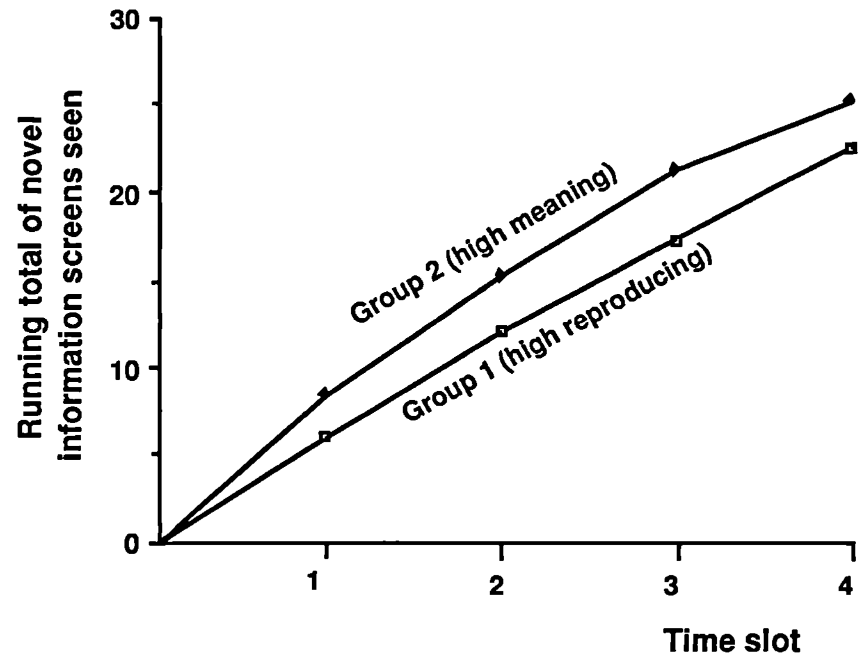


Figure 7.10 Consolidated novel information screens as function of time

7.7 Conclusions

The two groups were well-balanced in terms of their arts/science and male/female distributions so it can be confidently predicted that differences between the groups are due to their differing attitudes to study as identified by Entwistle's Approaches to Study Inventory. There were no differences in the learning outcome between the two groups, as measured by their performance in the examination paper. This seems to support the view that differences in the responses to the Inventory are not concerned with simply a general level of ability. The subjects' perceptions of the system, as judged by their responses to the subjective questionnaire, revealed that there was little difference between the groups.

Analysis of the log-files, however, showed some of the effects which had previously been predicted. Group 1 (high reproducing) demonstrated a preference for a more linear and structured presentation of the learning material. They made greater use of the tour facility, and the changing rate of tour usage with time between the groups may indicate that the two groups were using the tour facility for different purposes. Group 1 saw fewer screens than Group 2 (high meaning), but there was no difference in the number of novel information screens seen. Hence, Group 1 could be said to be the more efficient of the two groups. Alternatively, Group 2 could be said to be more active in that their *start-up* was quicker (i.e., activity in the first 7.5 minutes) and made greater use of hypertext links and, perhaps, the index facility. However, after this initial burst of activity by Group 1, both groups saw very similar numbers of novel information screens per unit time. Group 2 appear to be actively searching the material in order to form their own internal structure of the material, while Group 1 seem to be more content to follow prescribed paths and study each screen in more detail. Study of users' log-files can only answer some of our questions as they give us few clues as to the motivations of the users as to why they carry out certain activities.

CHAPTER 8

SUMMARY AND GENERAL CONCLUSIONS

8.1 Introduction

As stated at the beginning of this thesis, the prime aim of the research project was to produce a useful and usable piece of CAL software. More specifically, as a psychologist/educator/computer scientist, my intention was to produce a software package that was based on the digested wisdom of each of these disciplines; to capitalise on available psychological theories of attention, memory, perception and learning; to incorporate these within the framework of sound educational theories and approaches and to embed all within a computer system that provided a natural delivery vehicle. Was this an achievable aim?

My approach was necessarily influenced by my survey of available CAL materials (These on the whole had promised much and delivered little), on my subjective evaluation of our own students' requirements, and on what the computer technology could provide (naturally influenced by the financial constraints). I suppose that all designers assume that their efforts will result in the *ultimate* system. Whether our multidisciplinary approach, and specifically my attempt to ground the design in known cognitive and educational principles, enhances its efficacy is the real question. My principal objective was achieved in that the **Hitch-hiker's Guide** has received much use in the Department over a number of years. Evaluation studies, reported in Chapter 4, show the system to be easy to use, used for substantial periods of time by many students and often on a number of separate occasions. Subsequent data collection confirms that my perception of the system as being both useful and usable have been justified. The success is due in part to our concept of a learning support environment. To reiterate, my philosophy was that the learning process is complex and ill-understood, and that students would bring with them a diversity of learning styles and needs. It was not intended that my CAL system would be a replacement for any elements in the conventional educational process, but that it would be an additional supporting component. For this reason, we coined the term – learning support environment. Computer assisted learning systems should do just that – namely assist, and not be prescriptive. I accepted the need for the provision of a variety of navigational tools, which would ensure a flexible system where the locus of control could be shifted effortlessly between the user and the computer. This thesis has been concerned not only with the provision of these tools but with their use – by users with differing tasks and by users with differing learning styles – and the perception of the system by its users. The early awareness that navigational strategies differed, led me to explore some of the underlying reasons for this variability.

The extensive evaluation of the **Hitch-hiker's Guide** has shown that by using the system facilities (Chapter 4) and using them in an appropriate manner for their tasks (Chapter 5), subjects are clearly able to exploit the system with little or no prior instruction. This ease of use by the generally non-computer literate subject has been very satisfying. Nevertheless we feel confident with the interface provision for novices and experts alike. I also feel encouraged by the provision of the user interface within the metaphor of a travel holiday and believe that this concept has aided users in their learning and understanding of the system functionality (Chapter 4). There is also some evidence that the correct mix of navigational facilities is provided in the system for the necessary functionality without overcomplicating the interface (Chapter 5). Indeed our findings suggest that multiple provision of facilities was not only understood but led to more appropriate system usage.

Finally, I feel confident that my system design was the product of ideas, knowledge and expertise from the various disciplines listed above; rather than the product of technological abilities and *hype* that surrounded the initial excitement over hypertext systems. I was fortunate here, perhaps, in that my original work pre-dated this period. The remainder of this closing Chapter will present a brief summary of the thesis and its main findings, followed by some thoughts on outstanding problems and future directions.

8.2 Summary of Thesis

8.2.1 Chapter One

Chapter 1 gave a broad introduction to the many areas that both influenced and directed the design of the final system – in particular, the changing conceptions of the roles of education theory and educational practice. These changes in educational philosophy, along with continual technological developments, have given rise to a number of approaches to computer-based learning. The shortcomings (and advantages) of these were discussed along with the one approach that was to form the basis of my own approach – namely hypertext. The potential problems of hypertext systems – disorientation and inefficiency – were raised, as were suggestions for their solution. This Chapter finished by introducing the rest of the thesis, which could be described as having two objectives. Firstly, the design, development and evaluation of a system employed to supplement the teaching of cognitive psychology; and secondly, and more specifically, to look closely at the navigational issues raised by the provision and use of our own particular *navigational toolkit* – designed not only to overcome the problems of disorientation and inefficiency but actively to aid and encourage learning.

8.2.2 Chapter Two

Here, I detailed my particular philosophy of system requirements that were based on my desire to promote flexibility and freedom as key components in a learning environment, and led to the implementation of the listed cognitive principles within the framework of a hypertext connected information base. Chapter 2 also described how these underlying principles were realised as system features. These can be categorised in two classes. The first contains those features designed to strengthen the user's engagement with the materials and hence enhance their memorability or learnability (e.g., distinctive and dynamic presentations, interactive experiments, and multiple representations of materials and self-testing). The second class contains those features that were more associated with the structuring of the material: for instance, providing cross links for integration, and supporting a judicious association of materials not allowed by other media (i.e., static tutorials linked with the appropriate dynamic simulation of experiments), and supplying rich and varied access mechanisms to this material. These multiple access mechanisms were (a) to provide flexibility for the learner (based on our philosophy that it is the learner who should be in control), and (b) to provide a multi-purpose system for different user tasks and different user characteristics. It was this second category of features, specifically the navigational mechanisms, that I pursued in the following Chapters and experimental investigations. It would be wrong however to suppose that this seemingly loose category of structural features are not themselves important for learning. Navigation around an information space by conceptually associated links should not only extract the key information but also its overall structure and integral relationships. The Chapter demonstrates, via numerous examples, the realisation of the cognitive principles in the practical system.

8.2.3 Chapter Three

The implementations of both the presentation system (i.e., the interface as seen by the learner) and the authoring system are detailed. Though the lack of authoring tools and drawing packages forced me to develop (as far as my programming skills would permit) the system I wanted, it required many, many hours to be spent in specifying the system requirements, and writing, testing and debugging the resultant code. I apologise to the non-computer scientist for the size of this Chapter, and to the computer scientist for my non-formal approach to documentation.

8.2.4 Chapter Four

This Chapter describes the preliminary user testing of the full (but still developing) system as used within my Department to supplement the teaching of cognitive psychology. The aims of this evaluation were intentionally broad and open ended, and in some senses this was a time of development and evaluation of the evaluation methodology itself as well as the expanding system and courseware development. As an outcome of these preliminary evaluations, user feedback resulted in numerous changes to the software and courseware which I am sure have been critical factors in promoting its long-term usefulness. Despite these evaluations producing more insights than firm results, they were undoubtedly responsible for the direction taken in the experiments that followed both on the task and user characteristics studied and on the form of the data collected. By the end of these preliminary studies I was able to show that I had provided an LSE that was easy to use and perceived as successful for a range of user activities. These users had been shown to utilise a mix of navigational facilities rather than to rely on a *minimal* system, and it had been established that the metaphor and its embedded system functionality were understood. What was lacking from these evaluations was a clear link between user intention and user behaviour. An attempt to remedy this was made in the experiment detailed in the following Chapter.

8.2.5 Chapter Five

Preliminary evaluations highlighted much variability in the patterns of system use shown by different students, but the lack of knowledge of user intent during system interaction had so far made it impossible to account for these differing patterns. Clearly we would hope that students would utilise the facilities in ways dependent upon their tasks. Locating specific information would likely require different patterns of navigational behaviour than revising the material for an exam. To obtain evidence of the effect of task, and hence system utility, the "York Experiment" was designed and conducted. From this experiment it was seen that subjects do understand the facilities provided and use them in in an appropriate task-directed manner. Hence, there was an increased use of tours for exploration and learning and an increased use of the index facility for direct information seeking. What was pleasing about this experiment was that these effects were obtained when subjects were provided with the full set of navigation facilities. There was some evidence that the provision of a single *extra* navigational facility was ignored by users. This is a factor of interface design that would warrant further investigation. The beginning of Chapter 6 (in particular Section 6.2) summarises the specific findings at this stage of the project. Establishing that novice subjects could utilise the full system in an appropriate way, and with no apparent detriment to their subjective ratings of ease and success, meant that any further experimentation could be undertaken with the complete navigational provision. Once again, although I was able to show effects due to task, it was also clear from the individual data collected that differences between the users could not solely be accounted for by the task in hand. This led me to conduct the final experiment which is reported in Chapter 7.

8.2.6 Chapter Six

Before embarking on this final experiment it was necessary to review the background to our understanding of individual learner differences and individual learning strategies and styles. My main practical problem was how to characterise the subjects. A number of researchers have attempted to relate users' cognitive styles to their behaviour on computer assisted learning or information retrieval systems. An example of the former is Coventry (1989) on the provision of help facilities within the UNIX™ operating system. She compared students' performance with measures of their field-dependence – field-independence. Logan (1990) examined the behaviour of novice users of an on-line database against a series of tests to determine their learning style. On-going research at the University of Sheffield, by Clarke & Smith (1991), is examining the relationship between learning and cognitive styles and subject's use of a hypertext environment. These studies, together with others, indicate that there are some relationships between styles and system usage. Some of this work can be criticised on the grounds that inappropriate tests of a specific style are employed. The early part of this Chapter discusses the doubts surrounding the rigidity of such styles and, even, in some cases their existence. So it was my intention to take a more general measure of learning differences, and not a specific cognitive style or strategy, but a measurement designed to incorporate research from a wider range of disciplines. Entwistle's Approaches to Study Inventory was employed as this test attempts to incorporate various dimensions of a student's approach to study, deep/surface processing, the serial/holist dimension (as proposed by Pask), and various strategic and motivation elements. The Approaches to Study Inventory has received much use and evaluation, and some of the issues of robustness and stability are discussed in depth in this Chapter. Here I also presented details of my analysis technique based on the uncollapsed questionnaire scores rather than the usual method based on combining the scores in the various sub-scales prior to factor analysis. My analysis confirms the robustness of the two principal factors – Meaning Orientation and Reproducing Orientation. Finally, details are presented on the selection of the 36 subjects, from the pool of 310 students, who would take part in the experiment described in Chapter 7.

8.2.7 Chapter Seven

Having used the Approaches to Study Inventory to select my subjects for the experiment to produce two groups – one possessing a *high meaning/low reproducing* measure, the other a *low meaning/high reproducing* measure – I embarked on this final experiment with two goals. The primary goal was to demonstrate the effect the individual's particular set of characteristics might have on their pattern of interaction with the system. The secondary goal, secondary, not in importance but because it was more difficult to realise, was to measure differences in learning outcomes resulting from these differences in patterns of usage. A discussion of some of the difficulties involved in the measurement of learning generally was given in Chapter 6. As expected, we were more successful in our primary goal than our secondary one. The point to note is that cognitive style theories often assume an "equal but different" approach to learning, so the absence of any differences in learning outcome should not surprise us. Those subjects selected for their *high reproducing* approach to study, showed a preference for a more linear and structured presentation of the information and navigated the screens at a slower rate. The *high meaning* group demonstrated more active use, especially for their initial period of system use, showed greater use of the *self-determined* hypertext linkages as a navigational strategy, and appeared to be more actively searching the material. Could this possibly be their attempts to search for their own constructions of meaning? It would be pleasant to think that the lack of differences between the two groups, in both the subjective questionnaire and examination, were due to the success of the Hitch-hiker's Guide in providing a range of navigational tools and the transparency of the interface. However, such congratulation must await further experiments where, for example, restricted environments are provided to similar groupings of subjects.

This last experiment did show a much greater use of the map facility than had previously been recorded. This may reflect the task (i.e., learning of conceptually difficult and related materials) or it may generally reflect the advantage of the practice session in explaining (or demonstrating) the advantages of map use. The upward trend in usage throughout a session suggests that this facility is being used as an efficient mechanism for covering the information (by utilising the footprinting information available). Efficiency results in Chapter 5 would support this. What is highlighted here, however, are the limitations of our evaluation methodology. The next Section comments on our evaluation methodology.

8.3 Evaluation Methodology

Log-file data alone (even collected within a controlled experiment) cannot show clear user intent for complex navigational decisions. We have throughout this project (with minor exceptions in the prototype testing phase) employed techniques that rely on data collected from whole groups of subjects (sometimes an ill-defined group, sometimes a closely controlled group). My sources of data have been questionnaire responses and examination scores, and the fine detail of the subject's interactions with the system through their log-files. I have not questioned individuals either about their intentions as they used the system, through such techniques as *teach-back*, or probed their understanding of the presented knowledge base using, for example, concept mapping approaches. Such in-depth techniques can tell us more than, say, simple yes/no or even multiple-choice questions can. However, all techniques have their limitations – for example, if we believe that new knowledge is built on the existing knowledge base of the subject then, say, a tree-construction task will yield few clues as to how the new knowledge links to their existing knowledge base. I wished to discover some insights into how a sizeable body of diverse users would accept and navigate through the **Hitch-hiker's Guide**. As the first stage in this evaluation, it is necessary to determine the number and types of classes within the target population. If I had started by probing deeply the behaviour of very few individuals, then I may have remained ignorant of important classes of subject. Perhaps now, as I wish to enquire deeper into the motivations of students as they take a particular course of action or into the learning outcomes of exposure to differing material or differing presentational methods, is the time to commence using more in-depth techniques.

I have tended in the previous paragraph, and indeed the whole thesis, to consider evaluation as a psychologist and not as a practicing educator. Knussen, Tanner and Kibby (1991) have examined the evaluation of hypermedia in a wider setting – namely "to allow authors and learners to reap the benefits of this new environment." They consider the six models of evaluation, as proposed by Lawton (1980), within the context of hypermedia. These models are termed:–

- The classical experimental model
- The research and development (i.e., industrial) model
- The illuminative model
- The briefing decision-maker's (i.e., political) model
- The teacher as researcher model
- The case-study model.

I have focussed on the first and commented on the third but all methods have strengths and weaknesses, and as Knussen, Tanner and Kibby point out "a multi-faceted approach may ensure a wider perspective, but the cost of such an approach may not always be warranted in all cases."

8.4 Role of Hypertext in Education

As I discussed in Chapter 1, hypertext and hypermedia have been hailed as potential saviours of educational computing. Earlier, I quoted Kinnell (1988) as an example of the missionary zeal of the proponents of hypertext. One can find many such sentiments; for example, from Ted Nelson – one of the founding fathers of hypermedia – states:–

> "Anyone can choose the pathway or approach that suits him; with ideas accessible and interesting to everyone, so that a new richness and freedom can come to the human experience." (Nelson, 1981)

The language does often become religious in tone, the dawn of the New Age – to question is to be a heretic. But, in fact we have little information as to the success or otherwise of hypertext systems for learning, especially if we seek comparisons with traditional approaches.

I have employed the terms *surface* and *deep* in the context of learning styles in Chapter 6, and these terms are commonly used to describe not only a student's approach to studying but also the material to be learnt. Independent and deep processing of information is certainly a goal of tertiary education and Baird (1988) in a review article felt that not only was this the belief of teachers but that they thought that this progression towards independence should already be under way during secondary education. Kember & Gow (1989) discuss the predisposition of students to be surface or deep processors. Though deep processors will adopt a surface approach if this provides an advantage to them, the reverse is not evident. For surface learners, the "... transition between surface and deep predispositions is seen as difficult to influence". Henderson & Nathenson (1984) have suggested a number of methods that are designed to promote a deep and independent approach to learning, namely:–

- Advance organisers
- Activity-based exercises
- Case-study approach
- Project-based approach

Hopefully, our concept of learning support environments, which are more than just hypertext presentation systems, can promote some of these educational activities – in particular for the first two on this list. This is achieved not through the total freedom of hypertext but by the guidance offered by the supporting navigational facilities. The essence of activity-based learning is to take responsibility for the structuring of the learning away from the learner and place it in the care of the expert instructional designer (Laurillard, 1984). We should remain conscious of the possibility that *pure* hypertext may actually afford only surface processing through what is viewed by its supporters as its very strength, namely the effortless ease at which the user can "choose the pathway or approach that suits him".

The correct balance of navigational tools seems crucial in the successful design and application of hypertext systems to education. This not only implies further research into the implementation of such systems but also places a heavy burden on the authoring process. The authoring aspects of hypertext and hypermedia systems are an area that would repay careful examination, especially as they have received little attention.

8.5 The Future

I have explored what is in essence a simple hypertext presentation system though with the discerning addition of extra navigational facilities. The information base in terms of the number of screens is in the order of tens or at the most a few hundred. Technology offers us systems with multiple screens on very high-resolution monitors with on-screen live colour video and integrated speech output, and access to gigabytes of information. User interfaces, we are promised, will be adaptive and intelligently monitor the behaviour and aspirations of each individual user. Will we be in a better position to design and exploit such systems in education than we are for the *toy* systems of the present-day classroom or computer laboratory? Navigational issues will become even more important if all students are to benefit from these systems. It may not be appropriate to apply the findings from small hypertext-based CAL systems, such as the **Hitch-hiker's Guide**, to large multimedia systems. There is a danger that technological advances will, alone, set the pace of progress and not educational requirements. Despite these technological advances we should remain observant of the tasks, needs and processing competences of learners.

The Technology

... he also had a device which looked rather like a largish calculator. This had about a hundred tiny flat buttons and a screen about four inches square on which any one of a million 'pages' could be summoned at a moment's notice. It looked insanely complicated, and this was one of the reasons why the snug plastic cover it fitted into had the words DON'T PANIC printed on it in large friendly letters.

....

'What is it?' asked Arthur.

'*The Hitch Hiker's Guide to the Galaxy*. It's a sort of electronic book. It tells you everything you need to know about anything. That's its job.'

The Ideal?

... the *Hitch Hiker's Guide* has already supplanted the great *Encyclopaedia Galactia* as the standard repository of all knowledge and wisdom, for though it has many omissions and contains much that is apocryphal, or at least wildly inaccurate, it scores over the older, more pedestrian work ...

The Reality?

The *Hitch Hiker's Guide to the Galaxy* is a very unevenly edited book and contains many passages that simply seemed to its editors like a good idea at the time.

Douglas Adams, "The Hitch Hiker's Guide to the Galaxy" (1978)

APPENDIX A

GENERAL CLASS QUESTIONNAIRE (Chapter 4)

Please complete this questionnaire before you leave and place it in the box provided.
PASSWORD................................DATE............................TIME..........

Q1. WHY DID YOU USE THE SYSTEM?
(tick which ones are applicable, add any others of your own)

(a) For general browsing
(b) For finding out about a specific topic
(c) For essay preparation
(d) As a specific reading list
(e) For initial learning (before lectures)
(f) As a supplement to lectures
(g) For revision
(h) Others.....

Q2. WERE YOU SUCCESSFUL IN ACHIEVING WHAT YOU SET OUT TO DO? (please mark the most appropriate position along the scale)

very successful — completely unsuccessful
|---|

Q3. HOW EASY WAS THE 'HITCH-HIKER'S GUIDE' TO USE?
(please mark the most appropriate position along the scale)

very easy — very difficult
|---|

Q4. WHEN MIGHT YOU USE THE SYSTEM AGAIN?

(a) today
(b) during the next week
(c) during the next fortnight
(d) during the next four weeks
(e) during this week
(f) never

Q5. ANY OTHER COMMENTS?
(e.g., particular problems; suggestions for improvements; etc.)

APPENDIX B

EXTENDED QUESTIONNAIRE (Chapter 4)

- This questionnaire was designed by N. V. Hammond. This thesis utilises some of the data collected. A full analysis of the results for this questionnaire are given in Hammond & Allinson (1987).

- Solid lines, occurring between the questions, denote page breaks in the original questionnaire.

Microcomputer Teaching Questionnaire

INSTRUCTIONS

IMPORTANT: Read these instructions before turning the page

Write your password for the microcomputer teaching system below (please do not write your name anywhere on the questionnaire).

Your password:–

Please fill in the questionnaire without discussing it with anyone else or referring to anyone else's answers.

* **DO NOT go back to an earlier question and change your answers**

* **DO NOT look ahead for clues**

Now turn the page and answer the first question

1. The microcomputer teaching system lets you look at a variety of material about cognition. What "cover story" or "model" is used to help explain how you get around the material?

---

2. Write down all the different ways you can get from one "screenful" of material to another.

---

3. Write down all the different terms that appeared in the "boxes" at the bottom of the screen.

---

4. Which of the following terms appear in the "boxes" at the bottom of the screen? For each term, indicate how much confidence you have in your choice by putting a mark on the scale.

Term	Appeared? (Circle Yes or No)		How Confident?
ASSISTANCE	Yes	No	Guess--------------------------------------Sure
BACK ONE	Yes	No	Guess--------------------------------------Sure
BEGIN	Yes	No	Guess--------------------------------------Sure
CONTENTS	Yes	No	Guess--------------------------------------Sure
END SESSION	Yes	No	Guess--------------------------------------Sure
EXIT	Yes	No	Guess--------------------------------------Sure
GUIDE	Yes	No	Guess--------------------------------------Sure
HELP	Yes	No	Guess--------------------------------------Sure
INDEX	Yes	No	Guess--------------------------------------Sure
MAP	Yes	No	Guess--------------------------------------Sure
MORE	Yes	No	Guess--------------------------------------Sure
NEXT	Yes	No	Guess--------------------------------------Sure
OVERVIEW	Yes	No	Guess--------------------------------------Sure
PREVIOUS	Yes	No	Guess--------------------------------------Sure
QUIZ	Yes	No	Guess--------------------------------------Sure
READING	Yes	No	Guess--------------------------------------Sure
REFERENCES	Yes	No	Guess--------------------------------------Sure
RE-START	Yes	No	Guess--------------------------------------Sure
TEST	Yes	No	Guess--------------------------------------Sure
TOUR	Yes	No	Guess--------------------------------------Sure

5. Which of the following describe facilities that are available? In each case, indicate how much confidence you have in your choice by putting a mark on the scale.

Facility	Present? (Circle Yes or No)		How Confident?
Automatic tests which allows you to move on to advanced materials	Yes	No	Guess------------------------------------Sure
An "itinerary" of the screens that a tour visits	Yes	No	Guess------------------------------------Sure
A reading list on most topics	Yes	No	Guess------------------------------------Sure
Means of leaving a tour and re-joining it later	Yes	No	Guess------------------------------------Sure
An "index" of topics from which any one can be chosen	Yes	No	Guess------------------------------------Sure
"Bus stops" where you can join a tour at any stage	Yes	No	Guess------------------------------------Sure
A "map" of nearby screens from which selections can be made	Yes	No	Guess------------------------------------Sure
A central bus station from where any tour can be taken	Yes	No	Guess------------------------------------Sure
Selecting a bus to start a tour	Yes	No	Guess------------------------------------Sure
Multiple-choice tests on a topic	Yes	No	Guess------------------------------------Sure
A "glossary" giving the meaning of technical terms	Yes	No	Guess------------------------------------Sure
A list of relevant journals available in the library	Yes	No	Guess------------------------------------Sure

6. These are four different ways of accessing the material:

(a) Using INDEX
(b) Using MAP
(c) Going on a TOUR (selecting a bus)
(d) Choosing your own route (selecting "yellow" text on the screen)

You may have used different methods at different times. Write one or more of the methods – (a), (b), (c) or (d) – against each of the possibilities below:

(1) When know nothing about the material

(2) When slightly familiar with material

(3) When familiar with the material

(4) When browsing through material

(5) When getting material for a tutorial (eg for an essay or notes)

(6) When looking for other specific information (eg a reference)

(7) When revising for an exam

7. Now decide how useful you found these four methods to be. Please write down INDEX, MAP, TOUR, OWN ROUTE in order of usefulness (most useful method first):

8. Now think about how often you actually used the four methods. Please write down INDEX, MAP, TOUR, OWN ROUTE in order of frequency of use (the most frequent first):

9. The "cover story" used to explain how to get around the system is a travel holiday or travel guide. Even if you did not get this as an answer to the first question, please try and answer this one.

How useful was the cover story of a "travel holiday" in helping you understand how to get around the material on the system? (As a comparison, imagine a version which allowed you to do the same things, but didn't use terms like Map and Tour and didn't have pictures of buses). Mark a position on the line to indicate your choice:

Cover story made it worse	Not helpful at all	Cover story very helpful

|--------------------------------------|--------------------------------------|

10. How often did you "get lost" when using the system?

Very often	Never

APPENDIX C

MULTIPLE-CHOICE QUESTIONNAIRE (Chapter 5)

Please complete these questions. Just circle or tick the correct answer.

---

1. Where was the military headquarters of Roman York? On the site of the ....
Minster / Castle / Museum Gardens / Don't know

2. Monk Bar is on the road to ....
Hull / Scarborough / London / Don't know

3. The Red Tower is unusual because it is.........
Tallest part of Castle / built of brick / scene of battle / Don't know

4. Which Bar still has its Barbican?
Monk / Micklegate / Bootham / Walmgate / Don't know

5. Which Tower of the City Walls was built at the edge of the River Foss?
Multangular Tower / Red Tower / Fishergate Postern Tower / Don't know

6. Which Bar shows signs of Civil War damage?
Monk / Micklegate / Bootham / Walmgate / Don't know

7. Which is the highest of the Bars?
Monk / Micklegate / Bootham / Walmgate / Don't know

8. Why is no City Wall visible on part of the North side of the City?
destroyed in Civil War / natural earthworks / King's fishpond / Don't know

9. Where is the Eye of York?
Minster / York Castle / Stonegate / Don't know

10. Through which Bar did royalty enter the City?
Monk Micklegate / Bootham / Walmgate / Don't know

11. Name the Tower at the West corner of the Roman Fortress.
Multangular Tower / Red Tower / Fishergate Postern Tower / Don't know

12. In which century did the Angles come to York?
7th Century / 8th Century / 9th century / Don't know

13. Which Medieval City gate is sited on a Roman one?
Monk / Micklegate / Bootham / Walmgate / Don't know

14. On which Bar were the heads of Traitors displayed?
Monk / Micklegate / Bootham / Walmgate / Don't know

15. Name the most prominent remains of York Castle?

Clifford's Tower / Baile Hill / Stirling Mount / Don't know

16. What does the Rose Window in York Minster commemorate?

Marriage of Henry VII / Battle of Towton / World War II / Don't know

17. Who lived in St. William's College?

Minster Chantry Priests / Abbot of St Peter's / Sir Thomas Herbert / Don't know

18. King's Manor was originally the home of.........

Abbot of St Mary's / Thomas of Bayeux / William the Conqueror / Don't know

19. Which building is the official home of the Lord Mayor?

King's Manor / Mansion House / City Hall / Don't know

20. Name the Abbey ruins in the Museum Gardens?

St. Thomas's Abbey / St. Mary's Abbey / St. Peter's Abbey / Don't know

21. Where would you find the Pancake Bell?

Mansion House / Merchant Adventurer's Hall / Castle Museum / Don't know

22. In which part of York is the Merchant Taylor's Hall?

Parliament Street / Aldwark / Fossgate / Don't know

23. Where in York are the Mystery plays held?

Museum Gardens / Micklegate / Theatre Royal / Don't know

24. How do you enter the Chapel at the Merchant Adventurer's Hall?

over a bridge / through a trapdoor / spiral staircase / Don't know

25. What style of building is the Mansion House?

Medieval / Georgian / Victorian / Don't know

26. What building was the home of the King's Council of the North?

Merchant Adventurers' Hall / Treasurer's House / King's Manor / Don't know

27. The Minster is world famous for its.........

stained glass / crypt / decorated ceilings / Don't know

28. What is the name of the reconstructed street in the Castle Museum?

Ousegate / Castlegate / Kirkgate / Don't know

29. Who called York 'Jorvik'?

Romans / Saxon / Normans / Vikings / Don't know

30. Which Museum contains geology and natural history sections?

Yorkshire Museum / Castle Museum / Railway Museum / York Story / Don't know

31.Which Museum is part of the London Science Museum?

Yorkshire Museum / Castle Museum / Railway Museum / York Story / Don't know

32.What is the name of the City's Heritage Centre?

Yorkshire Museum / Castle Museum / Railway Museum / York Story / Don't know

33.Where is the entrance to the Viking Centre?

Petergate / Coppergate / Swinegate / Don't know

34.Where would you find the 'Printer's Devil'?

Goodramgate, / The Shambles / Stonegate / Don't know

35. What is the name of the window in the North Transept of York Minster?

Rose Window / Five Sister's Window / St. Peter's Window / Don't know

36. What are the oldest houses in Goodramgate?

Lady Row / Almy Terrace / Kettle Row / Don't know

37. What street is mentioned in the Domesday Book?

The Shambles / Coney Street / Stonegate / Don't know

38. Where would you see Minerva, Goddess of Wisdom?

Coney Street / Micklegate / Petergate / Don't know

39. Payement was the ....

place of execution /the street of butchers / the major Roman thoroughfare / Don't know

40. In what street is there a churchyard with stocks?

Petergate / Coney St. / Micklegate / Stonegate / Don't know

41. What is on top of the clock on St. Martin-le-Grand, in Coney Street?

Weather-vane / Admiral figure / Mayor of York / Don't know

42. Where would you find a 'Red Indian'?

Monk Bar / Petergate / Yorkshire Museum / Don't know

43. Which street was occupied by butchers?

Shambles / Pavement / Davygate / Don't know

44. Why was Margaret Clitheroe killed?

Because she was a .... *Catholic / Protestant / Witch / Don't know*

45. Why was a lantern hung in All Saint's Church?

To ward off evil spirits / mark Royal residence / To guide travellers / Don't know

46 In what period of history did the name for York mean 'the place of the wild boar'?

Roman / Viking / Saxon / Don't know

47. From what period is the famous Coppergate Helmet?

Roman / Saxon / Viking / Don't know

48. Who followed the Romans in York?

Vikings / Angles / Saxons / Don't know

49. Which Battle did Harold win in 1066?

Stamford Bridge / Towton / Marston Moor / Don't know

50. Who built two castles in York?

Emperor Claudius / Henry V / William I / Don't know

Thank you very much for your time. I hope you have enjoyed your 'trip' around York, and picked up a few interesting facts on the way. I hope you have an opportunity to see York for yourself, for as you have seen, it has plenty to offer the visitor.

Date..Group................................ Condition 1

APPENDIX D

EXAMPLE INSTRUCTION SHEET (Chapter 5)

This example is for the full facility system; for the restricted facility systems, the instruction sheet contains details of the relevant navigational methods only.

Reminders

You can get around the information in one of two different ways:–

1. By selecting the yellow text on any of the information screens.
2. By using the bottom line boxes.

The following bottom line boxes are available:–

Restart

This will take you back to the beginning, where you first started looking at the guide. From here you will be able to start your explorations again. Don't be frightened to use it.

Back-One

This will take you to the previous screen, repeated use of Back-One will retrace your steps back though the information.

Index

This will get you an index, rather like an index in a book. All the topics in the index are written in yellow and can therefore be selected.

Map

This will get you a show you a 'map' of the topics available in the Guide. This not only shows you what is available in the material in the area you are currently exploring, but it will also show you what information screens you have already visited and what screens you have still to visit. It also tells you where you currently are. All the text written in yellow is selectable, so you can use the map to get to the information you are interested in.

Tours

Whenever a picture of a coach is on the screen, you can go on a 'tour'. A tour is a pre-defined sequence of information screens, especially selected to cover the topic of the tour. Tours vary in size from a minimum of two screens to a maximum of 12. Whilst you are on a tour, the pointer, (the arrow) , changes into a coach.

Whilst you are on a tour, a special bottom line box called **'Next'** becomes available. The next screen of the tour is obtained by selection of this **'Next'** box .

If you decide to go on a tour, you need not stay on the tour, you can still select any yellow text on the screen or use the bottom line boxes available. If you do choose to leave the tour (by selecting other alternatives), you will find that the **'Next'** box is no longer available, instead, a box called **'Tour'** appears. This box allows you to rejoin the tour at any stage (like having the coach wait for you). Selecting the **'Tour'** box will take you to the screen you were on when you decided to leave the tour. The tour can then be completed in the usual way by selecting the **'Next'** box.

Try the system out now, this will all be made clear when you use it. Refer to these reminders if you need to.

APPENDIX E

SUBJECTIVE QUESTIONNAIRE (Chapter 5)

Please complete this questionnaire

Q1. HOW EASY WAS THE 'YORK TOURIST'S GUIDE' TO USE?
(please mark the most appropriate position along the scale)

very easy — very difficult

I---I

Q2. HOW OFTEN DID YOU GET LOST USING THE SYSTEM?
(please mark the most appropriate position along the scale)

never — very often

I---I

Q3. HOW MUCH OF THE AVAILABLE MATERIAL DID YOU MANAGE TO SEE?(please mark the most appropriate position along the scale)

0% — 100%

I---I

Q4. HOW SUCCESSFUL DO YOU THINK THE SYSTEM IS FOR LEARNING ABOUT YORK? (please mark the most appropriate position along the scale)

very successful — not at all successful

I---I

Q5.HOW DOES IT COMPARE WITH USING BOOKS FOR LEARNING?

better than books — same — worse than books

I--I--I

Q6. ANY COMMENTS?

Were there any facilities that you would have liked to have seen in the system, but were not available?

Thank you very much for your time

Date................................Group ....Condition..................

APPENDIX F

ANALYSIS OF LOG-FILE DATA (Chapter 5)

Tukey's Honestly Significant Difference (HSD) test use the general formula:–

$$HSD = q_{\alpha,\nu} \sqrt{\frac{MSE}{n}} ,$$

where n is the number of samples per cell, MSE is the relevant mean square error, and $q_{\alpha,\nu}$ is value from the normalised Studentized Range statistic at the α level of significance and ν degrees of freedom. For all tests, α is taken at the 0.05 level. The detailed calculations are based on those given in R. E. Kirk, *Experimental Design: Procedures for the Behavioural Sciences*, Wadsworth Publishing Company, 1968.

TSS - Total screens seen

2-Way Between analysis table:

Tests of significance for TSS using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	12943.75	70	184.91		
FACILITY	1106.67	4	276.67	1.50	.213
TASK	6265.80	1	6265.80	33.89	.000
FACILITY BY TASK	1267.33	4	316.83	1.71	.157

Table of means for TSS

	H	HI	HM	HT	HIMT
T1 (exp)	48.50	54.63	51.13	58.63	52.00
T2 (dir)	75.25	59.88	76.50	76.63	65.13

Tukey's HSD for task = 9.55

TNS - Total novel screens

2-Way Between analysis table:

Tests of significance for **TNS** using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	2283.88	70	32.63		
FACILITY	478.30	4	119.58	3.66	.009
TASK	1.01	1	1.01	.03	.861
FACILITY BY TASK	53.30	4	13.32	.41	.802

Table of means for TNS

	H	HI	HM	HT	HIMT
T1 (exp)	24.50	27.25	29.91	33.00	29.38
T2 (dir)	27.13	25.13	30.00	31.88	28.50

Tukey's HSD for facility = 2.69

TISS - Total information screens seen

2-Way Between analysis table:

Tests of significance for **TISS** using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	5496.25	70	78.52		
FACILITY	3239.30	4	809.82	10.31	.000
TASK	530.45	1	530.45	6.76	.011
FACILITY BY TASK	537.55	4	134.39	1.71	.157

Table of means for TISS

	H	HI	HM	HT	HIMT
T1 (exp)	29.25	33.50	27.25	46.13	33.13
T2 (dir)	40.13	32.63	37.88	52.00	32.38

Tukey's HSD for facility = 12.44
Tukey's HSD for task = 6.22

TNIS - Total novel information screens

2-Way Between analysis table:

Tests of significance for **TNIS** using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	2036.38	70	29.09		
FACILITY	503.20	4	125.80	4.32	.003
TASK	43.51	1	43.51	1.50	.225
FACILITY BY TASK	54.30	4	13.57	0.47	.760

Table of means for **TNIS**

	H	HI	HM	HT	HIMT
T1 (exp)	19.75	22.63	22.75	28.88	22.63
T2 (dir)	21.13	19.75	22.13	26.00	20.25

Tukey's HSD for facility = 7.57

P- % use of Back-one

2-Way Between analysis table:

Tests of significance for **P** using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	8217.70	70	117.40		
FACILITY	1701.09	4	425.27	3.62	.010
TASK	50.69	1	50.69	0.43	.513
FACILITY BY TASK	73.18	4	18.29	0.16	.960

Table of means for **P**

	H	HI	HM	HT	HIMT
T1 (exp)	24.82	16.12	11.19	11.01	10.18
T2 (dir)	22.86	18.02	12.72	13.95	13.72

Tukey's HSD for facility = 15.21

S - Percentage use of restart

2-Way Between analysis table:

Tests of significance for S using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	2340.34	70	33.43		
FACILITY	662.38	4	165.60	4.95	.001
TASK	209.82	1	209.82	6.28	.015
FACILITY BY TASK	30.10	4	7.52	0.23	.924

Table of means for S

	H	HI	HM	HT	HIMT
T1 (exp)	48.50	54.63	51.13	58.63	52.00
T2 (dir)	75.25	59.88	76.50	76.63	65.13

Tukey's HSD for facility = 8.12
Tukey's HSD for task = 4.06

N - Percentage use of hypertext

2-Way Between analysis table:

Tests of significance for N using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	8050.46	70	115.01		
FACILITY	13617.57	4	3404.39	29.60	.000
TASK	239.50	1	239.50	2.08	.153
FACILITY BY TASK	851.52	4	212.88	1.85	.129

Table of means for N

	H	HI	HM	HT	HIMT
T1 (exp)	64.60	60.10	64.12	25.72	37.81
T2 (dir)	61.89	57.96	63.87	34.65	51.27

Tukey's HSD for facility = 15.06

BLB - Percentage use of bottom-line boxes

2-Way Between analysis table:

Tests of significance for **BLB** using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	4666.16	70	66.66		
FACILITY	3750.97	4	937.74	14.07	.000
TASK	513.74	1	513.74	7.71	.007
FACILITY BY TASK	417.99	4	104.50	1.57	.193

Table of means for **BLB**

	H	HI	HM	HT	HIMT
T1 (exp)	35.41	39.90	35.88	17.62	28.74
T2 (dir)	37.98	42.04	36.13	24.61	41.58

Tukey's HSD for facility = 11.46
Tukey's HSD for task = 5.73

A - TNS as a percentage of TSS

2-Way Between analysis table:

Tests of significance for **A** using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	3872.72	70	5.32		
FACILITY	428.85	4	107.21	1.94	.114
TASK	4176.48	1	4176.48	75.49	.000
FACILITY BY TASK	254.76	4	63.69	1.15	.340

Table of means for **A**

	H	HI	HM	HT	HIMT
T1 (exp)	52.27	51.94	58.99	56.82	57.31
T2 (dir)	36.08	42.96	39.26	42.23	44.54

Tukey's HSD for task = 5.22

B - TNS as a percentage of the total possible screens

2-Way Between analysis table:

Tests of significance for **B** using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	9816.43	70	140.23		
FACILITY	2026.03	4	506.51	3.61	.010
TASK	2.62	1	2.62	0.02	.892
FACILITY BY TASK	242.27	4	60.57	0.43	.785

Table of means for **B**

	H	HI	HM	HT	HIMT
T1 (exp)	53.26	57.99	60.46	70.21	57.23
T2 (dir)	58.97	53.46	61.22	67.82	55.88

Tukey's HSD (p<.05) for facility = 16.63

C - TISS as a percentage of TSS

2-Way Between analysis table:

Tests of significance for **C** using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	8050.46	70	115.01		
FACILITY	13617.57	4	3404.39	29.60	.000
TASK	239.50	1	239.50	2.08	.153
FACILITY BY TASK	851.52	4	212.88	1.85	.129

Table of means for **C**

	H	HI	HM	HT	HIMT
T1 (exp)	60.78	61.23	53.69	78.39	64.15
T2 (dir)	53.22	54.39	50.12	68.05	51.26

Tukey's HSD for facility = 12.85
Tukey's HSD for task = 6.42

D - TNIS as a percentage of TISS

2-Way Between analysis table:

Tests of significance for **D** using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	6994.94	70	99.93		
FACILITY	1719.93	4	429.98	4.30	.004
TASK	4032.94	1	4032.94	40.36	.000
FACILITY BY TASK	895.36	4	223.84	2.24	.073

Table of means for **D**

	H	HI	HM	HT	HIMT
T1 (exp)	70.02	71.40	83.09	63.42	69.27
T2 (dir)	52.69	61.47	57.81	50.74	63.48

Tukey's HSD for facility = 14.04
Tukey's HSD for task = 7.02

E - TNIS as a percentage of the total possible screens

2-Way Between analysis table:

Tests of significance for **E** using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	12114.12	70	173.06		
FACILITY	2993.43	4	748.36	4.32	.003
TASK	258.84	1	258.84	1.50	.225
FACILITY BY TASK	323.26	4	80.81	0.47	.760

Table of means for **E**

	H	HI	HM	HT	HIMT
T1 (exp)	48.17	55.18	55.49	70.43	55.18
T2 (dir)	51.53	48.17	53.96	63.42	49.39

Tukey's HSD for facility = 18.47

APPENDIX G

ANALYSIS OF LONGITUDINAL DATA (Chapter 5)

Use of hypertext in *hypertext-only* (H) condition

2-Way Split-plot analysis table:

Tests of significance for Task using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
Within cells	161.38	14	11.53		
Task	150.06	1	150.06	13.02	.003

Tests of significance for X using UNIQUE sum of squares

Within cells	97.13	42	2.31		
(B)Facility use	25.81	3	8.60	3.72	.018*
Task by fac use	15.06	3	5.02	2.17	.106

* – HSD = 1.72

Use of index in *hypertext & index* (HI) condition

2-Way Split-plot analysis table:

Tests of significance for Task using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
Within cells	89.84	14	6.42		
Task	1.27	1	1.27	.20	.664

Tests of significance for X using UNIQUE sum of squares

Within cells	61.28	42	1.46		
(B)Facility use	9.92	3	3.31	2.27	.095
Task by fac use	2.55	3	.85	.58	.630

Use of map in *hypertext & map* (HM) condition

2-Way Split-plot analysis table:

Tests of significance for Task using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
Within cells	220.19	14	15.73		
Task	6.25	1	6.25	.40	.539
Tests of significance for X using UNIQUE sum of squares					
Within cells	143.81	42	3.42		
(B)Facility use	58.19	3	19.40	5.66	.002*
Task by fac use	11.50	3	3.83	1.12	.352

* – HSD = 2.09

Use of Tours in *hypertext & tours* (HT) condition

2-Way Split-plot analysis table:

Tests of significance for Task using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
Within cells	884.57	12	73.71		
Task	3.02	1	3.02	.04	.843
Tests of significance for X using UNIQUE sum of squares					
Within cells	780.86	36	21.69		
(B)Facility use	121.91	3	40.64	1.87	.152
Task by fac use	64.48	3	21.49	.99	.408

Use of hypertext in *hypertext , index, map & tour* (HIMT) condition

2-Way Split-plot analysis table:

Tests of significance for Task using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
Within cells	370.94	14	26.50		
Task	115.56	1	115.56	4.36	.056
Tests of significance for X using UNIQUE sum of squares					
Within cells	221.81	42	5.28		
(B)Facility use	12.88	3	4.29	.81	.494
Task by fac use	4.81	3	1.60	.30	.823

Use of index in *hypertext , index, map, tour* (HIMT) condition

2-Way Split-plot analysis table:

Tests of significance for Task using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
Within cells	47.44	14	3.39		
Task	39.06	1	39.06	11.53	.004

Tests of significance for X using UNIQUE sum of squares

Within cells	31.56	42	.75		
(B)Facility use	2.75	3	.92	1.22	.314
Task by fac use	5.19	3	1.73	2.30	.091

Use of map in *hypertext , index, map, tour* (HIMT) condition

2-Way Split-plot analysis table:

Tests of significance for Task using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
Within cells	79.59	14	5.69		
Task	.14	1	.14	.02	.877

Tests of significance for X using UNIQUE sum of squares

Within cells	45.53	42	1.08		
(B)Facility use	12.17	3	4.06	3.74	.018*
Task by fac use	4.05	3	1.35	1.24	.306

* – HSD = 1.17

Use of tours in *hypertext , index, map, tour* (HIMT) condition

2-Way Split-plot analysis table:

Tests of significance for Task using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
Within cells	260.34	14	18.60		
Task	102.52	1	102.52	5.51	.034

Tests of significance for X using UNIQUE sum of squares

Within cells	203.53	42	4.85		
(B)Facility use	15.80	3	5.27	1.09	.365
Task by fac use	3.92	3	1.31	.27	.847

Table of Means

	Task group	Interval 1	Interval 2	Interval 3	Interval 4
Hypertext in H cond	Exp	5.625	6.625	6.5	7.5
	Dir	9.0	8.625	11.0	9.875
Index in HI cond	Exp	1.25	1.75	2.125	2.5
	Dir	1.5	2.625	2.375	2.25
Map in HM cond	Exp	0.875	1.0	3.0	3.75
	Dir	2.5	2.125	2.375	4.125
Tours in HT cond	Exp	8.375	9.0	6.875	8.0714
	Dir	9.0	7.0	3.1429	9.5714
Hypertext in HIMT cond	Exp	4.125	3.625	4.625	5.25
	Dir	7.625	6.5	6.875	7.375
Index in HIMT cond	Exp	0.125	0.5	0.375	0.875
	Dir	1.75	2.375	2.5	1.5
Map in HIMT cond	Exp	0.5	1.5	1.25	1.875
	Dir	1.0	0.625	1.125	2.0
Tours in HIMT cond	Exp	2.875	3.875	4.0	3.625
	Dir	0.625	1.5	1.875	0.25

APPENDIX H

ANALYSIS OF SUBJECTIVE QUESTIONNAIRE DATA (Chapter 5)

2-Way Between analysis table: **Question 1**

Tests of significance for Q1 using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	10365.41	69	150.22		
TASK	3459.00	1	3459.00	23.03	.000
FACILITY	391.32	4	97.83	.65	.628
TASK BY FAC	247.18	4	61.80	.41	.800

2-Way Between analysis table: **Question 2**

Tests of significance for Q2 using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	20298.25	70	289.97		
TASK	4983.64	1	4983.64	17.19	.000
FACILITY	667.87	4	166.97	.58	.681
TASK BY FAC	1301.70	4	325.42	1.12	.353

2-Way Between analysis table: **Question 3**

Tests of significance for Q3 using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	41663.77	70	595.20		
TASK	3187.56	1	3187.56	5.36	.024
FACILITY	3882.65	4	970.66	1.63	.176
TASK BY FAC	4301.16	4	1075.29	1.81	.137

2-Way Between analysis table: **Question 4**

Tests of significance for Q4 using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	21271.99	69	308.29		
TASK	845.25	1	845.25	2.74	.102
FACILITY	2270.05	4	567.51	1.84	.131
TASK BY FAC	2274.93	4	568.73	1.84	.130

2-Way Between analysis table: **Question 5**

Tests of significance for Q5 using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	31591.78	70	451.31		
TASK	565.89	1	565.89	1.25	.267
FACILITY	1904.13	4	476.03	1.05	.385
TASK BY FAC	2675.40	4	668.85	1.48	.217

APPENDIX I

ANALYSIS OF PERCEIVED AND ACTUAL SYSTEM COVERAGE (Chapter 5)

2-Way Split-plot analysis table:

Tests of significance for T1 using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
Between Subjects					
A	3025.80	4	756.45	1.43	.245
Within cells	18533.75	35	529.54		

Tests of significance for T2 using UNIQUE sum of squares

Source of variation	SS	DF	MS	F	Sig of F
Within Subjects					
B	204.80	1	204.80	.75	.354
A by B	3313.70	4	828.43	3.02	.031
Within cells	9611.50	35	274.61		

Table of means

	b_1	b_2
a_1	49.25	75.63
a_2	59.25	63.13
a_3	60.63	47.75
a_4	73.63	71.88
a_5	58.38	58.75

Simple Main Effects

	b_1	b_2	ΣA
a_1	394	605	999
a_2	474	505	979
a_3	485	382	867
a_4	589	575	1164
a_5	467	470	937
ΣB	2409	2537	

Source	SS	df	MS	F	Sig
SS_A at b_1	2436.35	4	609.09	1.15	ns
SS_A at b_2	3903.15	4	975.79	1.84	ns
			(div 529.54)		
SS_B at a_1	2782.56	1	2782.56	10.13	**
SS_B at a_2	60.06	1	60.06	0.022	ns
SS_B at a_3	663.06	1	663.06	2.41	ns
SS_B at a_4	12.25	1	12.25	0.04	ns
SS_B at a_5	0.56	1	0.56	0.00	ns
			(div 274.61)		

** – significant at the 0.01 level (at least)

	0.05	0.01
F(4,30) =	2.69	4.02
F(1,30) =	4.17	7.56

APPENDIX J

APPROACHES TO STUDY INVENTORY
(Chapter 6)

Taken from the final research version of the Inventory in Entwistle & Ramsden (1983).

Attitudes to Study Questionnaire

Please complete the following:–

Name..College................................

Degree subject(s) being studied...

Please list subjects studied at 'A' level or equivalent

...

...

Complete the following by circling the most appropriate response:–

I generally put a lot of effort into trying to understand things which initially seem difficult	yes / no
I try to relate ideas in one subject to those in others, whenever possible.	yes / no
In reporting practical work, I like try to work out several alternative ways of interpreting the findings	yes / no
My main reason for being here is so that I can learn more about the subjects which really interest me	yes / no
Lecturers seem to delight in making the simple truth unnecessarily complicated	yes / no
I like to be told precisely what to do in essays or other assignments.	yes / no
The continual pressure of work-assignments, deadlines and competition makes me tense and depressed	yes / no
I chose my present courses mainly to give me a chance of a really good job afterwards	yes / no
Lecturers sometimes give indications of what is likely to come up in exams, so I look out for what may be hints	yes / no
I find it difficult to organise my study time effectively	yes / no
Often I find myself wondering whether the work I am doing here is really worthwhile	yes / no
I enjoy competition: I find it stimulating	yes / no
Ideas in books often set me off on long chains of thought of my own, only tenuously related to what I was reading	yes / no

Although I have a fairly good general idea of many things, my knowledge of the details is rather weak	yes / no
I generally prefer to tackle each part of a topic or problem in order, working out one at a time	yes / no
Although I generally remember facts and details, I find it difficult to fit them together into an overall picture	yes / no
I often find myself questioning things that I hear in lectures or read in books	yes / no
In trying to understand new ideas, I often try to relate them to real life situations to which they might apply	yes / no
I am usually cautious in drawing conclusions unless they are well supported by evidence	yes / no
I find that studying academic topics can often be really exciting and gripping	yes / no
I find I have to concentrate on memorising a good deal of what we have to learn	yes / no
I prefer courses to be clearly structured and highly organised	yes / no
A poor first answer in an exam makes me panic	yes / no
My main reason for being here is that it will help me to get a better job	yes / no
When I am doing a piece of work, I try to bear in mind exactly what that particular lecturer seems to want	yes / no
My habit of putting off work leaves me with far too much to do at the end of term	yes / no
Continuing my education was something which happened to me , rather than something I really wanted for myself	yes / no
It's important to me to do really well in the courses here	yes / no
In trying to understand a puzzling idea, I let my imagination wander freely to begin with,even if I don't seem to be much nearer a solution	yes / no
In trying to understand new topics I often explain them to myself in ways that other people don't seem to follow	yes / no
I prefer to follow well tried out approaches to problems rather than anything too adventurous	yes / no
I find it difficult to "switch tracks" when working on a problem: I prefer to follow each line of thought as far as it will go	yes / no
I usually set out to understand thoroughly the meaning of what I am asked to do	yes / no
I need to read around a subject pretty widely before I'm ready to put my ideas down on paper	yes / no

Puzzles or problems fascinate me, particularly where you have to work through the material to reach a logical conclusion	yes / no
I spend a good deal of my spare time in finding out more about interesting topics which have been discussed in classes	yes / no
When I am reading I try to memorise important facts which may come in useful later	yes / no
I tend to read very little beyond what's required for completing assignments	yes / no
Having to speak in tutorials is quite an ordeal for me	yes / no
I generally choose courses more from the way they fit in with career plans than from my own interests	yes / no
If conditions aren't right for me to study, I generally manage to do something to change them	yes / no
When I look back, I sometimes wonder why I ever decided to come here	yes / no
It is important for me to do things better than my friends	yes / no
Distractions make it difficult for me to do much effective work in the evenings	yes / no
I like to play around with ideas of my own even if they don't get me very far	yes / no
I often get criticised for introducing irrelevant material into my essays or tutorials	yes / no
I find it better to start straight away with the details of a new topic and build up an overall picture in that way	yes / no
Tutors seem to want me to be more adventurous in making use of my own ideas	yes / no
When I am tackling a new topic, I often ask myself questions about it which the new information should answer	yes / no
I find it helpful to 'map out' a new topic for myself by seeing how the ideas fit together	yes / no
When I am reading an article or research report I generally examine the evidence carefully to decide whether the conclusion is justified	yes / no
I find academic topics so interesting, I should like to continue them after I finish this course	yes / no
The best way for me to understand what technical terms mean is to remember the text-book definitions	yes / no
I suppose I am more interested in the qualifications I'll get than in the courses I'm taking	yes / no
One way or another I manage to get hold of the books I need for studying	yes / no
I'm rather slow at starting work in the evenings	yes / no

I certainly want to pass the next set of exams, but it doesn't matter if I only just scrape through	yes / no
I hate admitting defeat, even in trivial matters	yes / no
Often when I am reading books, the ideas produce vivid images which sometimes take on a life of their own	yes / no
I seem to be a bit too ready to jump to conclusions without waiting for all the evidence	yes / no
I think it is important to look at problems rationally and logically without making intuitive jumps	yes / no
I usually don't have much time to think about the implications of what I have read	yes / no
I find I tend to remember things best if I concentrate on the order in which the lecturer presented them	yes / no
Often I find I have read things without having a chance to really understand them	yes / no

APPENDIX K

INTRODUCTION TO HYPERCARD (Chapter 7)

K.1 Background

HyperCard is a programming environment for Apple Macintosh computers. At its most elementary level, it can be considered as an application program based on linear stacks of single screens (cards). The program contains integrated text entry and screen-painting facilities together with rudimentary database management tools. Through the use of a graphical interface, the user can easily manipulate a range of applications, such as personal diaries, databases and information providers. It has been employed to provide help systems to other application programs and interfaces to more complex database systems. A large range of stacks (mostly in the public domain) exist which attempt to introduce users to diverse subject matter. Most of these systems make little use of the in-built scripting facilities provided by the HyperCard environment. There was a great deal of media excitement at the launch of HyperCard; as it was seen as opening up the development of customised applications by individuals will little or no programming skills. Certainly at its lowest level, HyperCard does offer the abilities to design seemingly complex graphical user interfaces with little effort. This potential to "hack" together programs is partially reflected in the verbose and ill-structured functionality provided. Much of the initial enthusiasm has now died down, but HyperCard has certainly introduced to a much wider audience the advantages of working in an environment designed to fully exploit the graphical user interface of Macintosh and other computers. It should be remembered that many of these tools already existed, for example in the Macintosh Programmer's Workshop.

K.2 HyperTalk Scripting Language

The programming or scripting language is called HyperTalk. This is often referred to as an object-orientated programming language since it depends on the transmission of messages (which reflect actions) between objects. Objects may be buttons (screen hot-spots), text-fields, cards, backgrounds, stacks or more external resources such as menu commands, system resources, HyperCard resources and linkages to other applications, programs or peripheral control (e.g., video-players). The basic building block of HyperCard is the card with its associated background. A number of cards may share the same background, and a number of backgrounds may be used in one stack. A stack is an ordered set of cards. Cards may contain buttons, graphic areas or text-fields as objects, together with an overlay of graphical or textual information. Backgrounds may also contain such objects, for example a button on a background would be common to all cards sharing this background. Figure K.1 gives an overview of this card and background format.

HyperCard is event-driven, which means that nothing happens until an event triggers an action. Events can range from moving the cursor over an object, selecting menu items, the mouse clicked over buttons, and so on. Once an event occurs, a message is generated that identifies the event and this message is passed through a defined hierarchy to determine what action, if any, should take place as result of this message. The message hierarchy of HyperCard is illustrated in Figure K.2. The user initiates a message by activating (say) a button or a card. If the first object in the message hierarchy does not make use of this message (i.e., it does not contain an appropriate message handler that checks for this event) then the message continues up to next level in the hierarchy. A typical code segment for a message handler would be:–

```
on mouseUp -- that is the mouse button is released
           -- and this message is sent to current card
  go to third card of background 3 of stack "Trees"
  pass mouseUp
end mouseUp
```

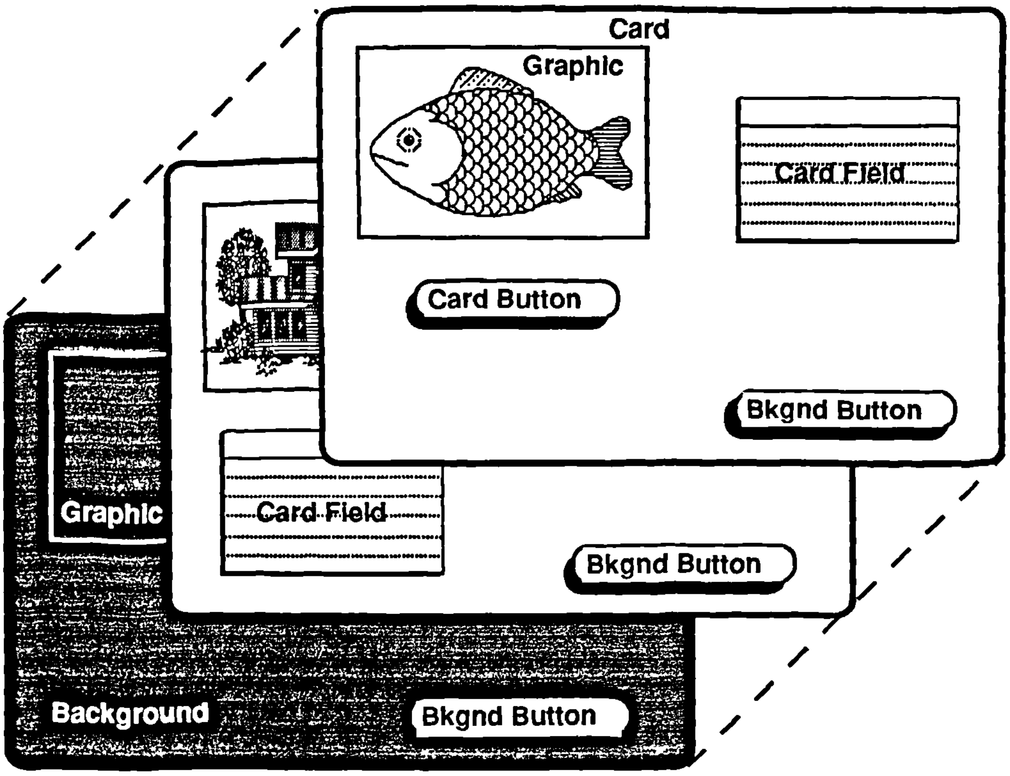


Figure K.1   Basic arrangement of HyperCard

The message will not proceed further than the first valid message handler, unless it is explicitly sent further up the hierarchy – in this case by the command `pass mouseUp`. An understanding of the message passing mechanism of HyperTalk is essential to understanding the following brief description of how Hitch-hiker's guide was implemented in HyperCard.

All the segments of HyperTalk, which are distributed throughout the HyperCard stack, are in the form of message handlers. For example, when a card is opened its HyperTalk script will contain a handler of the following general format:–

```
on openCard
  -- do something
close openCard
```

Every object in the stack (e.g., buttons, cards, backgrounds, the stack itself) can be associated with a number of message handlers. This distributed form of programming makes the adherence to a formal and well-structured programming style difficult, and does little to assist the debugging process.

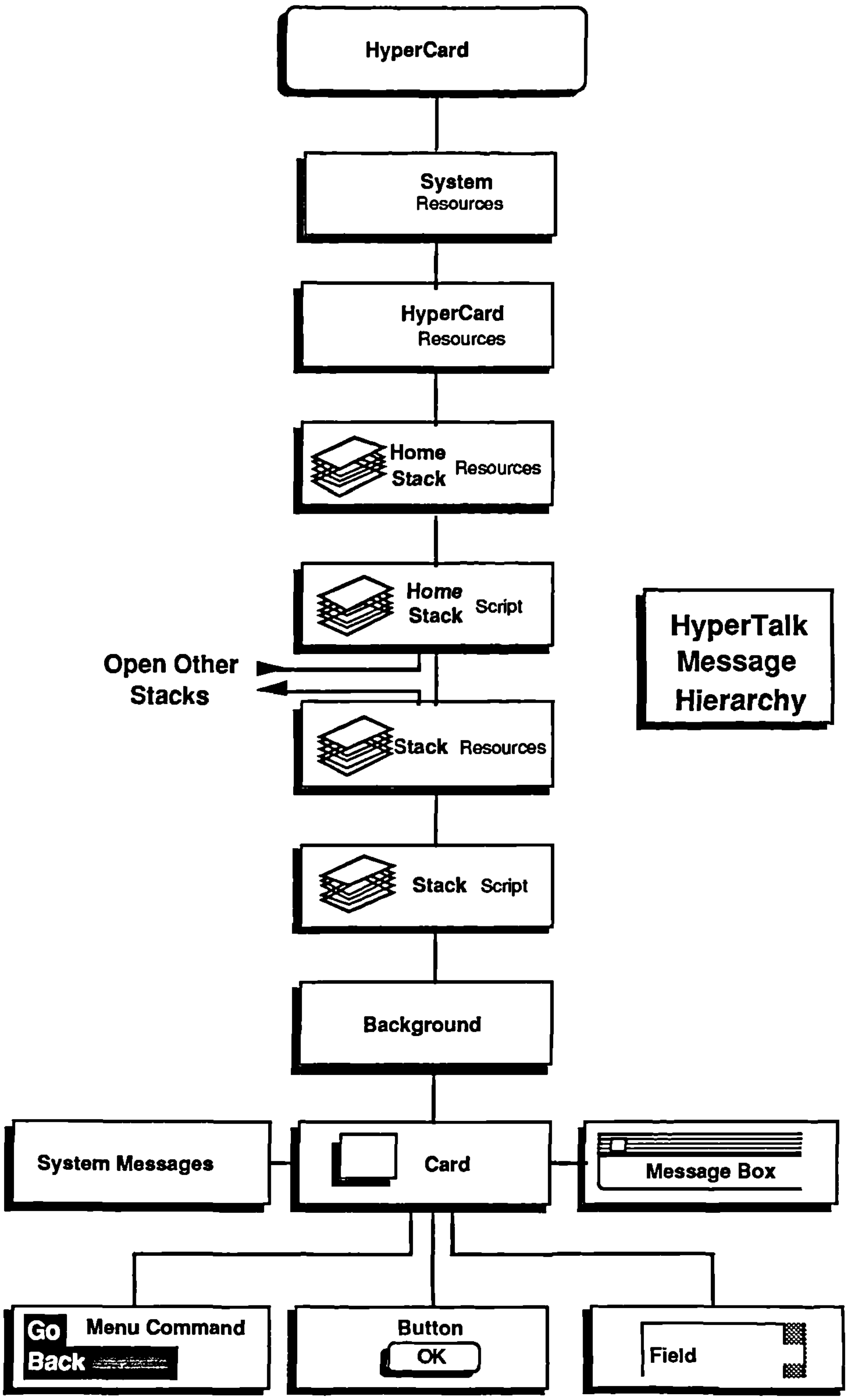


Figure K.2 Message hierarchy of HyperCard

HyperTalk is a verbose language, with often a number of syntax variations possible in order to achieve the same effect. There are approximately 450 different commands, functions, mathematical functions and tools available in Version 1.2.2 of HyperTalk. Some commands are very powerful: for example, visual effects and controlling the computer's resources; however, other features are very rudimentary (e.g., external file handling). No attempt will be made here to describe the language in full, and reference should be sought to the numerous books published on HyperCard and HyperTalk. The code segments given below should be fairly self explanatory; however, a short note on global and local variables is felt advisable as they are often ill described.

Local variables exist only within a single message handler. They are created when a handler is invoked and cease to exist when the handler is exited. Global variables remain in existence and retain their values in all handlers and objects that declare them. For example, the following code segments will exhibit different behaviour:–

```
on getUserName
  global userName
  ask "What is your name:'
  put it into userName
  sayHello
end getUserName

on sayHello
  answer "Hello, " & userName
end sayHello
```

This will cause an error, since `userName` does not exist in the handler `sayHello`. It should read:–

```
on sayHello
  global userName
  answer "Hello, " & userName
end sayHello
```

Worse still, the following handler will not clear the global variable `userName` and does not report an error:–

```
on clearUserName
  put empty into userName
end clearUserName
```

APPENDIX L

QUESTION SHEET
(Chapter 7)

Question sheet

Name ....Date..............

Please answer the following questions by writing your reply in the spaces provided. Open ended question require only a sentence or two, many other questions require you only to fill in the missing words or to label diagrams. If there are questions that you can't answer, then leave them blank and continue. PLEASE DO NOT RETURN TO ALTER OR COMPLETE EARLIER QUESTIONS.

Q1 What are the three mechanisms that either singly or in various combinations are responsible for the control of physiological processes in man?
....
....
....

Q2 The contractile tissue in the walls of the heart is called ....
Its most characteristic physiological feature is that it contracts, exerting a moderate amount of tension and it does not readily 'fatigue'.

Q3 The following questions relate to the human cardiac cycle.

a. How long is the single cycle?
....

b What is the period between the beginning and the end of ventricular contraction?
....

c. Does the auricle show large pressure changes?
....

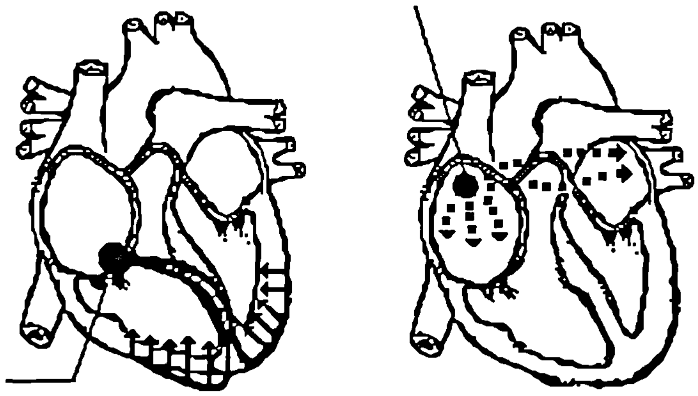
d. Describe the relationship between the electrocardiogram and the pressure changes in the auricle and ventricle.
....
....
....

Q4 The electrical changes pass partly from muscle to muscle cell, but they are conveyed more efficiently by a system of modified cardiac muscle cells called
....

Q5 Electrical activity can be recorded on a...........................- a slowly revolving smoked drum. Each contraction and relaxation of the heart is recorded as a peak or a depression in the tracing.

Q6 The beat starts at the ....and the cells of the .... show a wave of electrical activity (the P wave of the electrocardiogram). As this wave passes along the Purkinje fibres, the muscles of the auricle contract. The.................. is then activated and electrical activity passes along the Purkinje fibres(as the QRS wave) and the..................muscles then contract.

Q7 Label the SA and VA nodes and the Purkinje fibres of the auricle and ventricle



Q8 What name is given to that part of the nervous system concerned with the control of functions not normally under voluntary control?
....

Q9 Underline the appropriate words (shown in italics) in the following passage:

The parasympathetic nerve to the heart (called the vagus) ends near the SA node. When the nerve is active, the SA node sends out *fewer/more* impulses, the strength of contraction of the cardiac muscle is *reduced/increased*, and the interval between the contractions of the auricles and ventricles is *reduced/increased*. The heart rate *slows down/accelerates*.

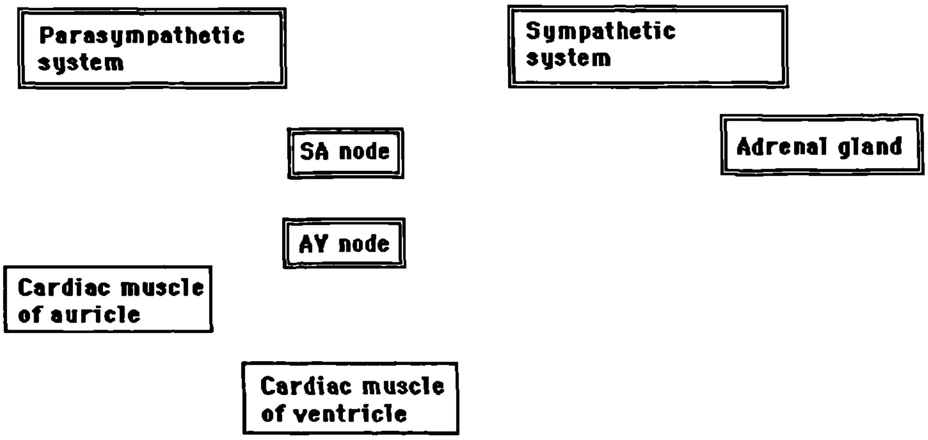
Q10 Why is there a similarity between the effects of adrenalin and the stimulation of the sympathetic nervous system?
....
....
....

Q11 What is the effect of acetylcholine on heart rate?
....
....

Q12 Thyroxin has widespread effects on body cells, speeding up metabolism and the production of heat. Too little or too much will both cause deleterious effects in man so it is essential that the secretions of the thyroid gland should be continuous and at an appropriate level. This is controlled by ....

Q13 Reconstruct the following flow diagram by adding the links to the boxes shown. Mark clearly which physiological mechanism each link represents by choosing from the given list (a, b or c).

Labels
a. The system of cells within the heart that act directly on the cardiac muscles.
b. Parts of the nervous system that can alter the rate of the heart beat.
c. Effects of hormones on heart beat.



Q14 To maintain ....- the state of optimum functioning or flow - a ....mechanism is required to monitor the flow and regulate the rates of processes (or activities of organs).

Q15 Give an example of each of the following:-

a. a hormonal feedback mechanism
....
....

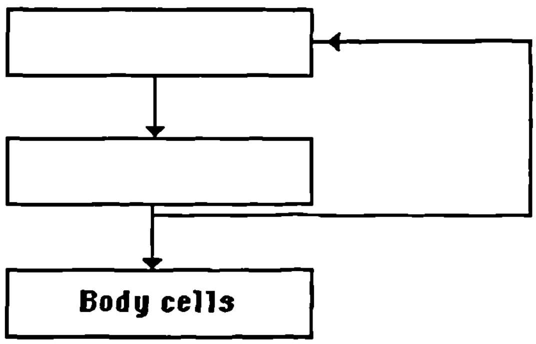
b. a nervous and hormonal feedback mechanism
....
....

c. a nervous feedback mechanism
....
....

Q16 An increase in the amount of thyroxin in the blood causes the pituitary gland to secrete less TSH. What is the effect of this?
....
....

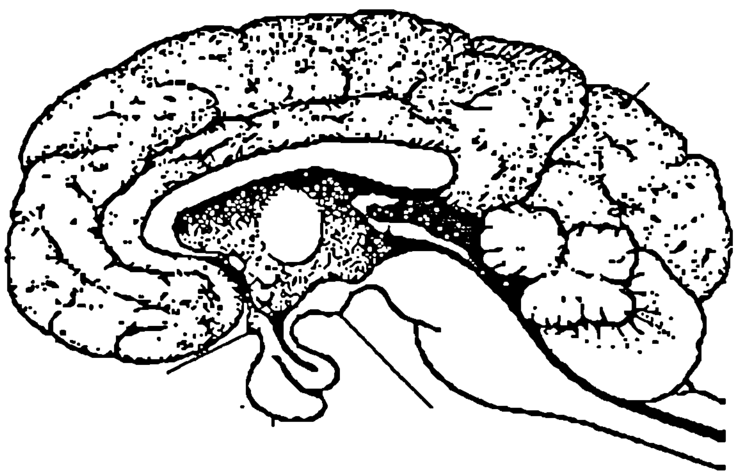
Q17 Complete the following flow chart by labelling the unmarked boxes and the unmarked arrows with the labels provided.

TSH in blood	Pituitary gland
Thyroxin in blood	Thyroid gland



Q18 Label the following diagram with the labels provided.

Hypothalamus
Pituitary gland
Crossing of the optic nerves
Cerebral cortex



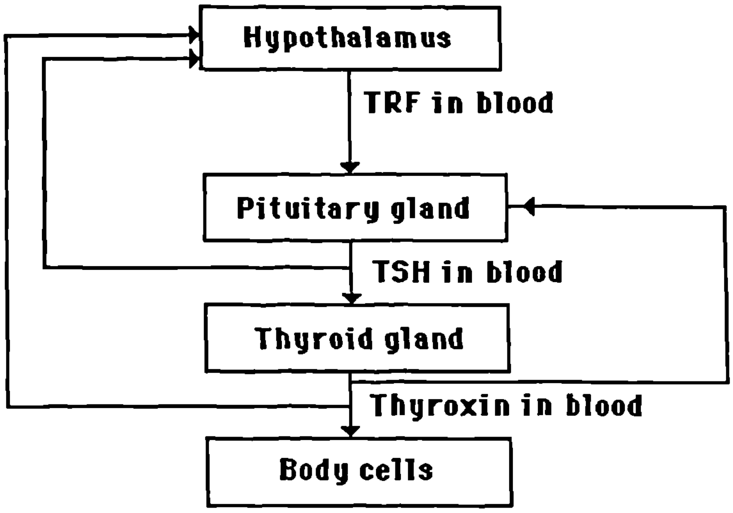
Q19 The stimulus to raise and maintain the level of circulating TSH comes from that part of the brain called the ....

Q20 Some of the cells in the hypothalamus are ....that is these cell bodies secrete substances that pass down the axons and are released at the other end. Some of these cells secrete a substance called TRF. What does TRF stand for?

....

Q21 Complete the diagram by placing the correct labels (given below) alongside the unmarked feedback loops.

1. A high level of thyroxin inhibits
2. TSH inhibits TRF
3. Low level of thyroxin stimulates



Flow diagram to show the control of thyroxin reaching the body cells

Q22 What are the pacemakers?

....

Q23 Which part of the autonomic nervous system a) accelerates the heart beat?

....

b) slows down the heart beat?

....

Q24 What hormone increases the heart rate?

....

Q25 What are the two feedback mechanisms responsible for temperature control in man?

....

....

APPENDIX M

INSTRUCTIONS FOR PRACTICE SESSION
(Chapter 7)

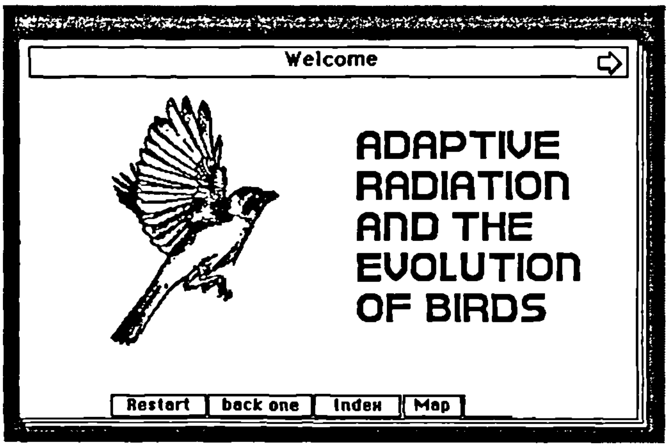
Instructions for practice session

Learning to use the computer

This is a demonstration to introduce you to the computer system. You will learn how to use the mouse and how to find your way around the information. Do not spend time learning (or even reading) the material presented, but use it merely to help you gain confidence with the computer.

Please follow the instructions carefully.

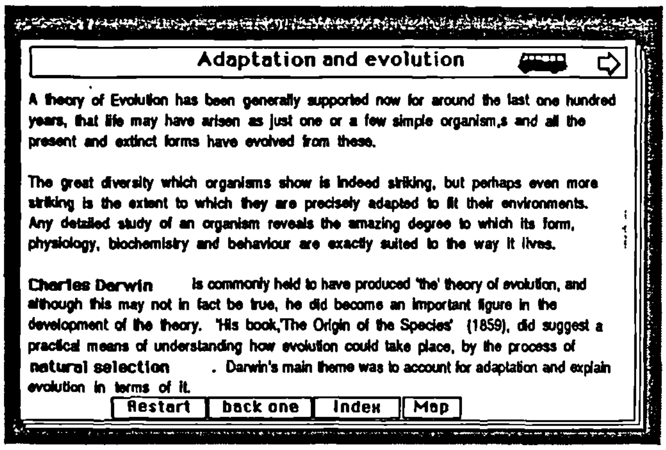
This is the 'Welcome' or start screen. In the top right hand corner you will see an arrow.



You will find an arrow in this position on the screen only if there is more information available on the topic. Clicking on this arrow is like turning the page of a book.

1. Move the mouse pointer to the arrow and press the mouse button

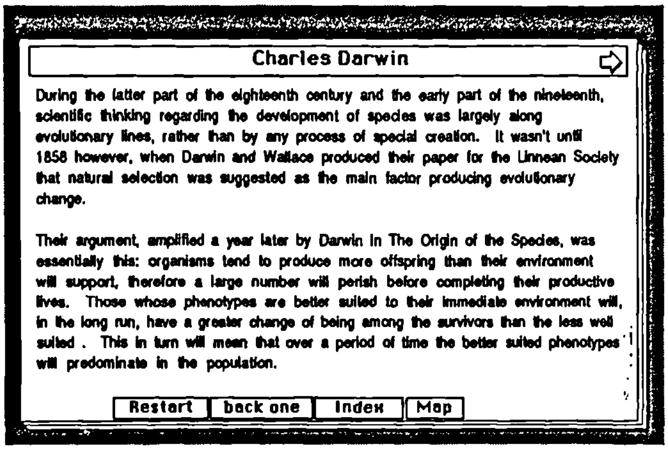
The next screen appears:-



On this screen you can see some words are shown in a bold text. These are topics for which there is more information. Clicking on this text will take you to this further information.

2. Move the mouse pointer to the text '**Charles Darwin**' and press the mouse button

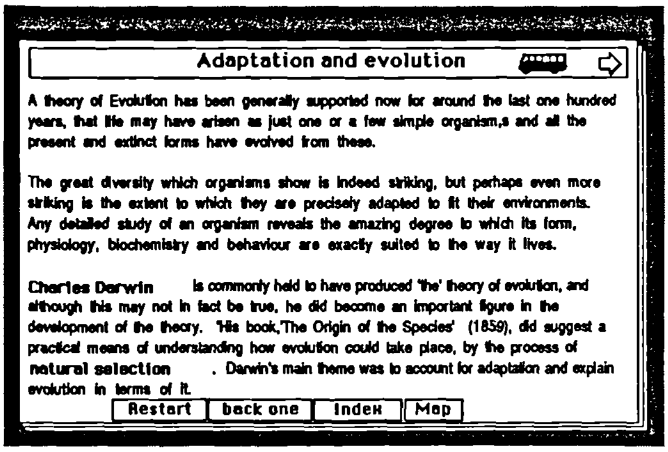
A new screen entitled 'Charles Darwin' is displayed:-



If you want to go back and check on something on a previous screen you can use the 'Back-One' facility:

3. Move the mouse pointer to the box 'Back-One' at the bottom of the screen and press the mouse button.

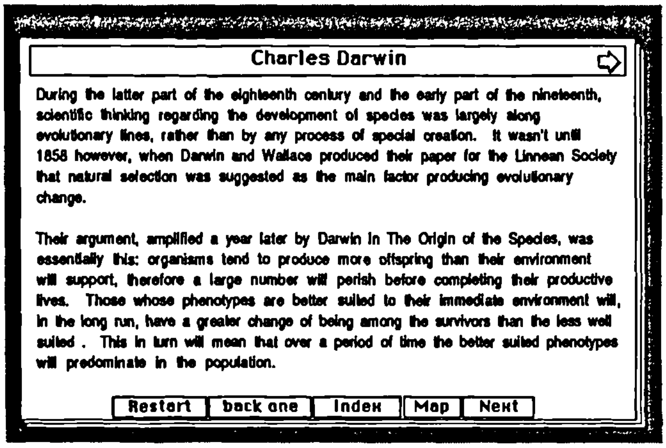
The previous screen is again displayed:-



Notice on this screen that in the top area of the screen there is a small picture (icon) of a bus. This bus icon indicates that a tour of the information on this subject is available. A tour is a sequence of screens that display the information on a particular subject in a logical order. Tours can take you through as many as ten screens of information. Often they are a lot shorter, the shortest being only two screens long. A tour is like taking a bus tour around a strange city. If you complete the *City* tour you will end up back at the place you started from. Completing a *tour* of the material will always return you to the screen from where you started the tour.

4. Move the mouse pointer to the bus icon and press the mouse button.

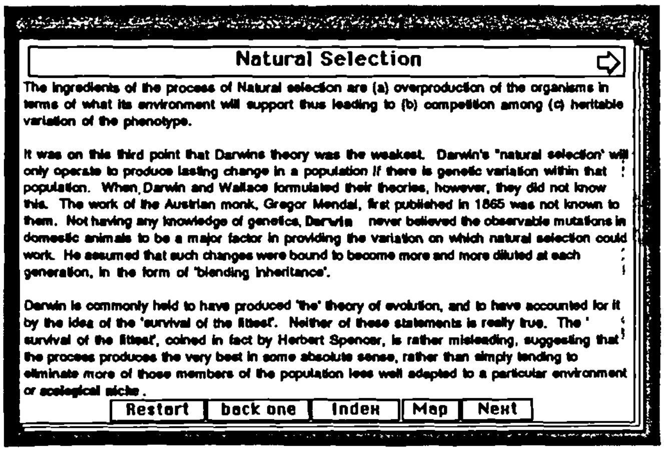
The following screen appears:-



You will now notice a box entitled 'Next' is present at the bottom of the screen. Clicking on this box will take you to the next screen of information on this tour.

5. Move the mouse pointer to the box 'Next' and press the mouse button.

The screen changes to display the following:-



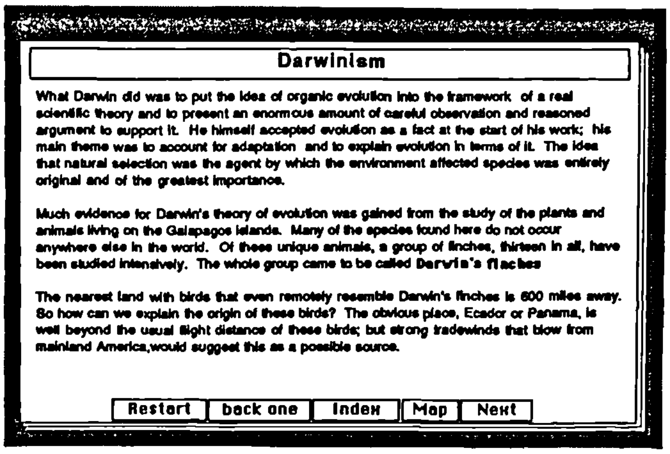
6. Repeat step 5 until you get get back to the start screen of the tour. (This means that you will need to select the 'Next' box a total of 8 times. Stop when the screen entitled '*Adaptation and evolution*' (tour start screen) is re-displayed.

The 'Adaptation and evolution' screen is displayed. The tour has now been completed.

Note that the 'Next' box has now disappeared. You have finished the tour. You could choose to do it again of course by selecting the bus icon again! You will find that several tours exist within the material, their availability will be indicated by the presence of the bus icon.

Choosing to go on a tour does not mean that you will be forced to complete all the screens of a tour. You can divert from the tour at any stage and rejoin it later (at the screen you left from)

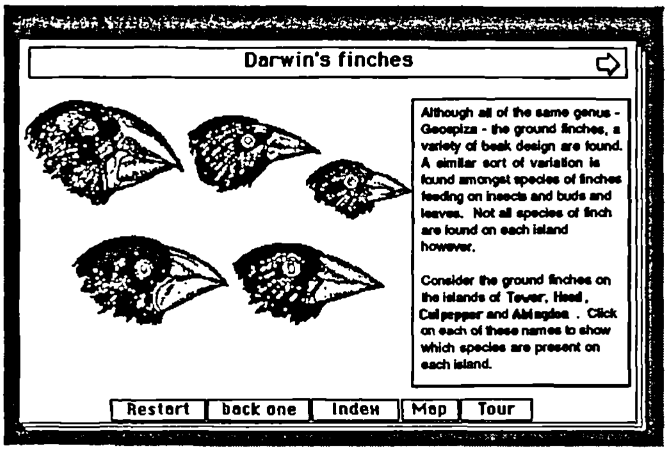
7. Select the bus icon again and press the mouse button, continue on the tour (by clicking on the 'Next ' box until the following screen is displayed:-



This time we will not select the 'Next' box but some **bold** text

8. Point to the text '**Darwin's finches**' and press the mouse button

The following screen is displayed:-



Notice that the 'Next' box is replaced by a 'Tour' box. If you want to return to the tour at the screen from which you left it , then you use this 'Tour' box. We will do this now.

9. Point to the 'Tour' box and press the mouse button

Notice that the screen returns to the last screen of the tour you were on. The 'Tour' box once again becomes a 'Next' box, and the tour can be continued as normal.

<u>The bottom line boxes</u>

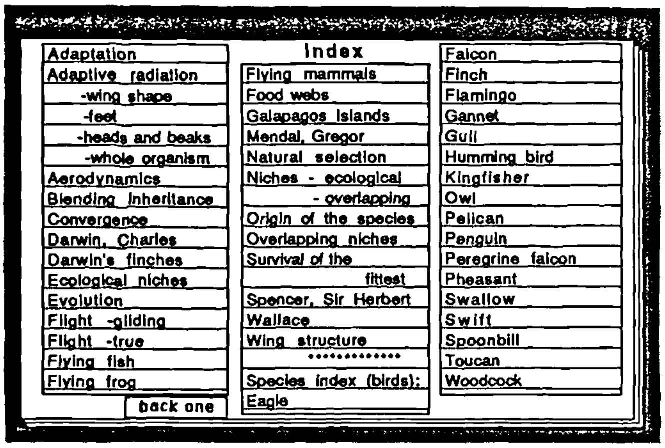
We have already used the the 'Back-One' and the 'Next'/'Tour' boxes. Now we will explore the other available boxes.

10. Point to the 'Restart' box and press the mouse button

The 'Welcome' screen appears. The 'Restart' facility is good if you become *lost* in the material and feel that you need to get back to the starting point. There are, however, other ways to find your way about the information, namely the <u>*index*</u> and the <u>*map*</u> facilities.

11. Point to the 'Index' box and click the mouse button.

The Index screen is displayed:-



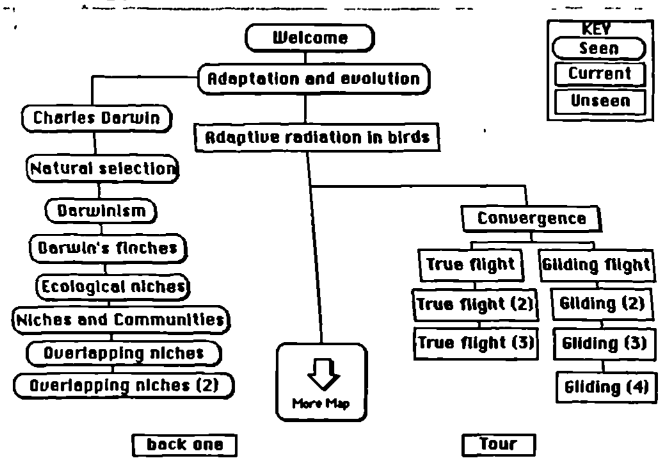
Each item in the index can be selected for more information.

12. Select the text '**Convergence**' and click the mouse button.

Information on *Convergence* is displayed.

13. Select the 'Map' box and click the mouse button.

The following screen appears:-

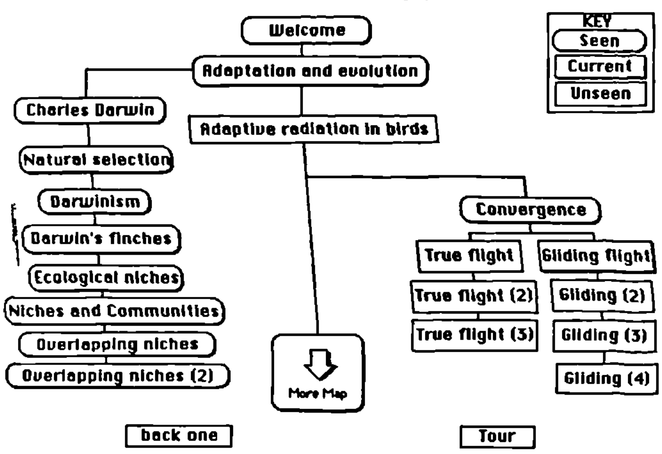


The Map is similar to an index, but shows the relationship of the different screens to one another. Each of the items on the map represents a screen of the information. The map can help you to see how the information is structured, both in the computer and conceptually.

A further use of the map is to indicate where you have been, and where you have just come from. Notice the Key in the top right-hand corner. The rounded boxes indicate screens that you have already visited; the rectangular boxes, the screens that you have not yet seen; and finally the shadowed box - *Convergence* - indicates the screen you have just come from.

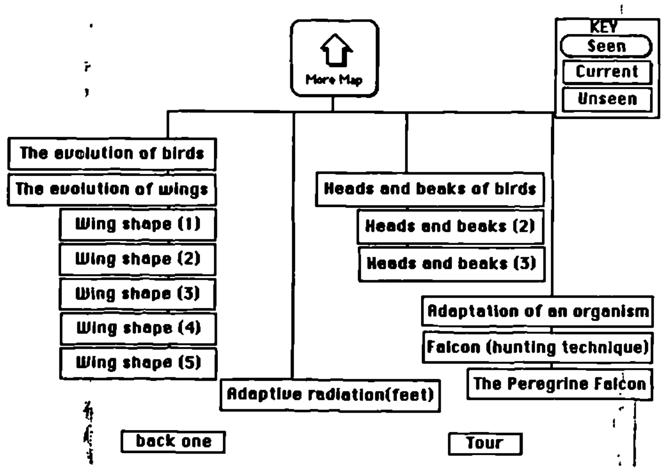
14. Select *Gliding Flight* (a screen you have not yet visited) and press the mouse button

15. Select the 'Map' box and click the mouse button to return to the *Map* screen



16. Select the arrow labelled *More Map*.

A further map of the information is displayed:-



<u>To recap: You can get around the information in the following ways:-</u>

1. Selecting the **bold text** on the screens, or by selecting the arrow (➪) in the top right-hand corner.

2. Going on a **Tour**, which is a prescribed sequence of screens. This should cover a topic in a logical order.

3. Use the **Index** if you know what you are looking for and want to get directly to it.

4. Use the **Map** if you want to see how the information on the different screens relate or/and you would like to know which screens you have/have not seen.

5. **Remember:** You can use a combination of the above methods

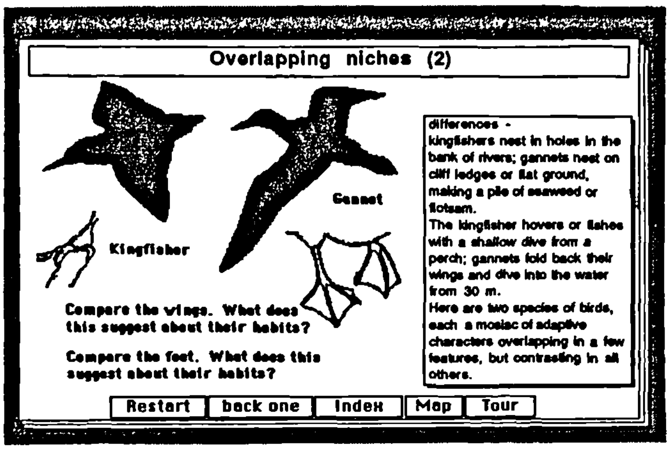
<u>One last thing to know</u>

There is one final source of information within the text that is not automatically displayed on the screen. This is the 'hidden' answers to the questions that are posed throughout the screens.

Wherever a question is posed in the text, the answers can be displayed by simply selecting the question and pressing the mouse button. We will try this now.

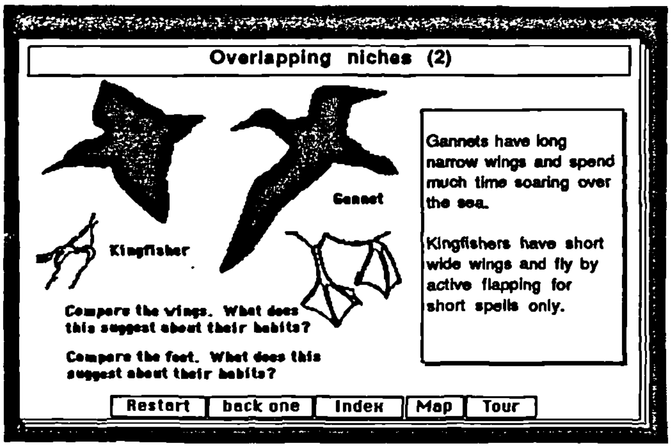
17. Select the arrow labelled 'more map' and press the mouse button. (This will return you to the 'first'or 'top' map). From this map select the box labelled 'Overlapping niches (2)'

The following screen is displayed:-



18. Select the question *'Compare the wings. What does this suggest about their habits?* and press the mouse button.

The screen changes to the following:-



The answer to the question is displayed. Now try clicking on the second question. With most of the other examples you will come across, answers to all the questions on a screen can be displayed at one time.

Complete the following tasks: this is for you to explore the system yourself

19. Use the *Index* to find information on the adaptation of a whole organism. (you may need to follow this up by using the *bold text* or *arrow*).

20. Use the *Map* to find information on Ecological Niches. (you may need to follow this up by using the *bold text* or *arrow*).

21. Use the *Tour* to find information on Convergence. (you may need to use the *index* or *map* to get to the relevant area of information).

APPENDIX N

SUBJECTIVE QUESTIONNAIRE (Chapter 7)

Name ______________________________ Date ________________

- **How easy was the computer system to use?**

Very easy				Very hard
1	2	3	4	5

- **How successful do you think the computer was in presenting the material?**

Very successful				Very unsuccessful
1	2	3	4	5

- **How does learning material in this way compare with learning the same material from a book?**

Much better		About the same		Much worse
1	2	3	4	5

- **Did you enjoy using the system?**

Very much				Not at all
1	2	3	4	5

- **Please rank the features you found most useful in navigating between the computer screens?**

Use the following notation

1 = most useful
2
3
4 = least useful

clicking **BOLD TEXT** or ⇨	
using the map	
using the tour	
using the index	

- **How difficult was the material you were asked to learn?**

Very difficult				Not at all difficult
1	2	3	4	5

APPENDIX O

ONE-WAY ANALYSIS OF VARIANCE TABLES (Chapter 7)

Data collected from this experiment was analysed using **Systat 5** on an **Apple Macintosh**

Subjective Questionnaire data analysis

Question 1: How easy?

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	0.111	1	0.111	0.531	0.471
ERROR	7.111	34	0.209		

Question 2: How successful?

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	0.028	1	0.028	0.058	0.811
ERROR	16.278	34	0.479		

Question 3: How does learning material this way compare with learning the same material from a book?

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	2.778	1	2.778	2.591	0.117
ERROR	36.444	34	1.072		

Question 4: Did you enjoy using the system?

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	0.250	1	0.250	0.353	0.556
ERROR	24.056	34	0.708		

Question 6: How difficult was the material you were asked to learn?

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	4.694	1	4.694	5.781	0.022
ERROR	27.611	34	0.812		

Analysis of examination paper

Score for 'Total meaning 'questions

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	56.250	1	56.250	0.108	0.745
ERROR	17757.389	34	522.276		

Scores for 'Total reproducing' questions

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	513.778	1	513.778	1.500	0.229
ERROR	11645.222	34	342.507		

Total scores (complete paper)

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	49.000	1	49.000	0.132	0.718
ERROR	12586.556	34	370.193		

Log-file analysis

Total screens seen

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	10781.361	1	10781.361	5.144	0.030
ERROR	71261.389	34	2095.923		

Total novel screens seen

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	668.223	1	668.223	2.471	0.125
ERROR	9195.914	34	270.468		

Percentage of hypertext navigations

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	182.250	1	182.250	3.415	0.073
ERROR	1814.500	34	53.368		

Percentage of index navigations

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	21.778	1	21.778	4.275	0.046
ERROR	173.222	34	5.095		

Percentage of tour navigations

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	560.111	1	560.111	4.526	0.041
ERROR	4207.444	34	123.748		

Percentage of map navigations

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	0.694	1	0.694	0.020	0.888
ERROR	1169.611	34	34.400		

Percentage of back-one navigations

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	13.444	1	13.444	0.211	0.649
ERROR	2164.556	34	63.663		

Time spent on practice stack

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	4.375	1	4.375	0.454	0.505
ERROR	327.705	34	9.638		

Number of screens seen on practice stack

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	121.000	1	121.000	0.138	0.713
ERROR	29810.889	34	876.791		

Screen presentation rate during practice session

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	0.010	1	0.010	0.003	0.959
ERROR	27.499	34	3.750		

Efficiency

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	1034.694	1	1034.694	8.657	0.006
ERROR	4063.716	34	119.521		

Note quality

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	14.694	1	14.694	2.312	0.138
ERROR	216.056	34	6.355		

Note quantity

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	7.111	1	7.111	1.785	0.190
ERROR	135.444	34	3.984		

Notes: use of diagrams

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
GROUP	1.000	1	1.000	0.206	0.653
ERROR	165.000	34	4.853		

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