Links in Hypertext: An investigation into how they can provide information on inter-node relationships

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Abstract

This thesis posits that there exist relationships, with distinguishable meanings consistently recognisable across people and not specific to a single information domain which can be used to improve the power and usefulness of hypertext links. Further to this is that the extending of this concept of a finite set of general purpose relationships has application in the wider area of information systems.

The concept of hypertext is fully documented, and its chief components and problem areas explored in some detail. The focus of study is then refined to look more closely at hypertext links. The features of hypertext links and the conceptual framework that underlies them is discussed. In particular, the use of the name of a hypertext link as a means to convey the link's meaning is looked at. Then, the role that hypertext links may play in some of the problems encountered in hypertext usage is examined.

The question of what semantics hypertext links should communicate is then addressed and it is hypothesised that the addition of more semantic information to the links in hypertext systems will alleviate certain usability problems. The further hypothesis that this should be done in a way that is independent of the subject matter of the information being linked is argued. Means of testing these hypotheses are investigated. The idea of applying existing models of text organisation to add meaning to hypertext links is rejected, and the requirements for an empirical approach are established.

A series of four empirical studies is introduced, aiming first to investigate what relationships between pieces of information can be identified by people, secondly to summarise these identified relationships into a set of semantic relationship types, thirdly to test the usefulness of these relationships as link types in a hypertext system, and fourthly to examine how well these links communicate information about what they link. Each investigation is reported, and their results and implications discussed.

The experimental programme as a whole is evaluated, and the implications of the resulting set of link types for hypertext designers and users are discussed.

Finally, the areas in which the concepts put forward in the thesis could be extended are investigated. In particular this includes the necessity for the relationships arrived at to be applied to different text types and different reading tasks. Ways in which these extensions could be achieved are outlined.

1: Introduction

1. BACKGROUND

Computers are used by people for work, entertainment, and to assist in a variety of ways in their daily lives. Human-Computer Interaction (HCI) is the study of the interaction of people and computers in the performance of tasks. It is studied in its own right and as a component of other disciplines, such as Computer Science and Psychology.

The interaction between a person and a computer involves information passing from one to the other. Typically, information will pass from the person to the computer via a keyboard and a mouse, and from the computer to the person via a screen. A constraint that bears on virtually every aspect of HCI is the limited nature of this information exchange. The interaction, due to the physical limitations of the computer hardware and the user's perceptual limitations, is a bottleneck between the user and the computer.

There is on the one hand the capabilities of the user and computer and on the other hand, the limitations of the interaction between these. This disparity will remain a challenge for HCI and will grow as computers become more powerful, as computer memory and storage devices become cheaper and able to store more, and as computers around the world become more interconnected.

Currently, software to facilitate the interaction between computer and user gives the user access to tools to control the flow of information and filter information, at any time aiming to present only that information which the user wants or needs. As computers develop as described above it will become ever more important.

A pertinent example is in the field of large-scale information systems. Information is held at computer sites around the world which are connected together on the Internet. With the aid of various software tools, users have access to this information. There are problems for the user in obtaining what they want due to the vast amount of information available, the poor way in which it is referenced, and the lack of powerful tools to manipulate it. These usability problems result in the user having to look at a high proportion of 'useless' to 'useful' information, or simply not finding what they want. In this field, there has been much excitement recently over the "information

superhighway". The implication is that this is the answer to all our information needs, and will somehow deliver what we want at the touch of a button. In fact this is far from the truth; it is new in name only and derives from a popularising of the Internet through such developments as the World-Wide Web (WWW), and tools to support this which, while they make existing methods of information retrieval easier to use, do not offer very much that is new. They chiefly support a 'browsing' style of access to information, where the user is not searching for any definite thing but is moving around an information space in a 'reactive' fashion, choosing their next location based on what they are presented with.

The point is that although, over the years, the number of people using networks such as the Internet as sources of information has grown, and the information available has increased greatly, the tools available to filter and present that information have improved little more than cosmetically. The promised benefits of computer-mediated access to information are not apparent, and frequently the investment in time necessary to find something is no less than if the information was being sought from a conventional paper-based library.

The problems seen here with access to information on large networked systems are true also of information access on a smaller scale, where the information the user wants may be on a single computer or CD-ROM . While the volume and usage of such systems has increased, the tools have not improved and difficulties still remain for the user in gaining access to the information they want.

This thesis looks at hypertext systems; they merit investigation because the principles behind them are used in access to information over computer networks as well as in small systems on individual computers. In addition, with the rapid spread of access to computer networks, their use is growing and thus it is important that shortcomings in their effectiveness as a tool for information retrieval are identified and remedied. Hypertext systems will be discussed fully in the next chapter, but they are an example of a type of system whose purpose is to present information (usually textual) under the command of the user. Hypertext systems are loosely structured graphs, with 'nodes' of information connected by 'links'. In these systems the user moves from one piece of information to another by activating explicit links between the pieces of information. The ideas behind these systems were first proposed in the first half of this century (e.g. Bush, 1945 and Wells, 1938) but despite wide use, they have not changed significantly since their first development.

The motivation for the research described here came from the need for hypertext tools which supported the users' information retrieval and the urgency given to this need

by the increasing development of hypertext-like systems without any overall improvement in their usability.

2. GOALS

The goal of this work was to find ways to improve access to information in hypertext, and to make it easier for hypertext users to navigate around that information in a constructive fashion. As a starting point this work focused on the links in hypertext as these form the primary means for communicating to the user where information lies in the hypertext system, and are also the primary means for the user to control what information is displayed. The goal of this thesis was to find a means by which links in hypertext systems could be enhanced so as to provide a greater level of support for the users in efficient access and retrieval of relevant information.

There are two, clearly different ways of going about this. Starting from the idea that links in hypertext should have more semantic information attached to them, the first method would be to undertake a thorough and systematic investigation to identify what this information was, what effect it had, and to unambiguously assess the validity of these results. It would be necessary to show that whatever enhancements this method concluded ought to be made to hypertext links were both justified and had taken into account all relevant information. The second method is weaker in terms of the conclusions that can be drawn from it and would seek not to investigate the validity of an approach, but to identify a plausible framework for looking at hypertext links and then to show that using this as a basis for enhancing hypertext links was useful and practical, and that it was feasible to use and develop this approach. A distinction between the methods is that the first would show how, why and under what conditions adding particular semantics to hypertext links gave rise to what kinds of usability benefits, whereas the second would show only whether they gave rise to any usability benefits. The second method could be a preliminary step, to determine whether it was worth embarking on the first, investigative method, and precisely what needed to be addressed with this method.

The first of these methods would be extremely difficult to undertake for two reasons:

- Firstly (and this will be seen in chapter 2) the field of hypertext suffers from a lack of definition. The components of hypertext, the tasks for which hypertext is used, and the relationships between these are poorly defined. Lacking a firm basis of knowledge about hypertext, it would be difficult to say anything absolute about the nature of hypertext links. Performing a rigorous investigation into any aspect of hypertext links without a

substantial amount of preliminary work would run the risk of basing a lot of effort on ill-founded assumptions.

- Secondly (and this is related to the first point) the range of types of hypertext and types of tasks for which hypertext is used is broad as well as being undefined. So if this research resulted in an enhancement to hypertext, it could not be assumed that it was generally applicable to all hypertext usage. So although it might be possible to demonstrate the validity of an approach within a narrow area of hypertext usage, a feasibility study which by its nature can be more easily extended and modified would be more useful.

An approach that sought to test the veracity of a theory of hypertext linking would be premature given the lack of a coherent framework for investigating hypertext. Also an approach that sought to show the feasibility of an idea would be more practical. For these reasons it was decided to adopt the latter approach and the aim was to develop an initial understanding of how hypertext links might be enhanced and then to show that this had some plausibility and practical value in a subset of hypertext and that further investigative work was merited.

3. CONTRIBUTION

This thesis concentrates on the links in hypertext systems, looking at them as tools to control the presentation of information and argues that they are not providing users with either the necessary support for navigation or the information about the structure and semantics of the hypertext that they need. It examines a way of formalising the linking structures in hypertext systems to alleviate problems of unpredictability and inconsistency in their behaviour.

The need for work such as this to be done arises from the current state of hypertext systems, their linking structures and their authoring tools. Examination of these systems shows that their construction and their linking methods are in most cases fairly unsophisticated. This leads to the failure of these systems to provide to their users the information which they want from the hypertext.

This thesis examines the current situation, looking at what information the links in hypertext systems give or fail to give their users and what problems this leads to. It then examines what information the links could give their users and how this is constrained by the difficulties of hypertext authoring. The problem is that although one could have a hypertext system in which every element of it, each individual link, had been laboured over and comprehensively tested to ensure that it gave precisely

the 'right' level of assistance and information to the user, this is in practice not possible as it would make authoring a hypertext system unrealistically expensive. Conversely it is necessary to avoid the problems bought about by 'cheap' authoring, where pieces of text are just simply linked together and the user is given no explanation of why they should follow a particular link.

This thesis then resolves this problem by arguing for a reusable set of expressive links, which would not incur the authoring costs of having each individual link 'custom-made' yet whose links could be used to communicate information about their meaning and purpose to the user.

The characteristics that this set ought to have are then looked at, and the basis that is then used for developing it is that the links should enable their users to anticipate to some degree the text that is at the end of the link. Reports are then given of how the links were successfully developed and tested.

The principal contribution of this thesis is that it has shown the feasibility and practicality of the idea of enhancing hypertext links by adding descriptive relationships to them, where these relationships form a small, general-purpose set. This demonstrates the potential for increasing the usability of hypertext links while not making the authoring task unrealistically complex.

This approach can now be used as the starting point for further, more investigative work looking at the same issues, and also for work in related fields such as devising authoring methods.

The set of link types is not developed in this thesis beyond an experimental stage. That is, although they demonstrate the concepts on which they were based, they are not developed to a state where they could be used in a hypertext system of any size where a large investment of time and money in the authoring process is needed.

However, the set of link types is only one of the principal results of this thesis. Equally important are the identification of the need for such a set of link types, the demonstration of how a working set of such link types can be developed, and the implications these have for other areas of information systems design.

The man contributions this thesis makes can be summarised:

- The current state of hypertext development is examined and the requirements for a set of link types which provide useful information to the hypertext user and yet which can be authored are established.
- A means for deriving such a set of link types is developed.
- A set of link types is developed and reported.

- The implications of this work and the directions in which it needs to progress are examined.

4. ORGANISATION

To enable the reader to find their way around, each chapter will be briefly summarised:

- Chapter 2: Hypertext
  This chapter discusses hypertext, chiefly looking at what it is, and what usability problems are associated with it.
- Chapter 3: Links
  Continuing from chapter 2, this chapter focuses on hypertext links in some depth. Chapters 2 and 3 provide background and impetus for the hypotheses behind this thesis. Chapter 3 concludes by looking at first theoretical and then empirical approaches to the testing of the hypotheses.
- Chapters 4 and 5: Experiments
  These two chapters provide the detail of the experiments done to test the hypotheses. Chapter 4 concerns the experiments done to arrive at a set of link types, and chapter 5 concerns the testing of these link types.
- Chapter 6: Implications
  The results, from the two preceding chapters provide implications for hypertext systems and these systems' authors and users, and in this chapter these implications are discussed. In addition, the implications of the methodology used to arrive at the set of link types for future research is discussed.
- Chapter 7: Conclusions
  Finally, the thesis is concluded, and the areas where future work is needed are set out.

5. TERMINOLOGY

A short comment on terminology used in this document: In research literature relating to hypertext, the word "hypertext" is often used to describe a particular hypertext system, for example, "A hypertext was built and tested...". Here, as much as possible, when a specific implementation is referred to, it will be called a "hypertext system" whereas the term "hypertext" will be reserved either for an abstract notion of what hypertext is, or the general topic area of hypertext.

2: *Hypertext*

"...so quick bright things come to confusion."
(A Midsummer Night's Dream)

1. INTRODUCTION

This chapter will provide the reader with a guide to the field of hypertext. It will cover the main areas of hypertext study.

This chapter contains six sections:

- A description of hypertext
- Definitions of hypertext
- A brief history of hypertext
- Descriptions of many of the components of hypertext
- Descriptions of some of the problems associated with hypertext
- A summary of some of the current research issues in hypertext

Firstly, it is necessary to ask what makes hypertext a worthwhile area of study and why effort should be expended on problems associated with it. Textual information is now so commonly supplied by computer that having information supplied by a computer rather than getting it from people or books is no longer unusual. Thirty years ago such commonplace access to computer-based information would have been thought remarkable, and it may be assumed that in thirty years from now, computers will be used to answer even more of our information needs, and by an increasing number of people.

While hypertext is by no means the only way to gain access to computer-based text, it is notable for having the possibility of making a model of the information available to the user. Reference to this model may then enable the user to 'navigate' the information with ease. Hypertexts are also based on a simple interaction, and are designed to be 'easy to use'. For these reasons, hypertexts, and hypertext-like systems will increase in use, and therefore their problems merit study. Also, the problems of hypertext usage are likely to be related to wider problems of representation of information by computer, and so it is hoped that study of these problems in the field of hypertext may shed light on more general issues.

2. DESCRIPTION OF A 'TYPICAL' HYPERTEXT SYSTEM

This section will outline some of the characteristics of a typical hypertext system. As shall be seen in later sections, there is really no such thing as a typical hypertext. However if the reader is unfamiliar with the field, this section will be useful in explaining what is most often meant by the term 'hypertext', and what may be expected from such a system. The description of the system that follows is not meant to represent any actual system nor is it meant to comprise a definition of hypertext, and none of its parts should be considered prerequisites for a hypertext system.

This hypothetical system runs on a computer with a mouse and a high resolution screen with a sophisticated windowing system. The hypertext has a large number of discrete nodes, containing text and graphics, which have connections between them in the form of links. The links are binary, and each link connects a single word or phrase in one node with the whole of another node. Also, the links can only be seen in the node in which their 'source' (the single word or phrase) is. As well as this 'network' type of link, there are also hierarchical links which represent the nodes in a hierarchy and allow the user to move through this hierarchy.

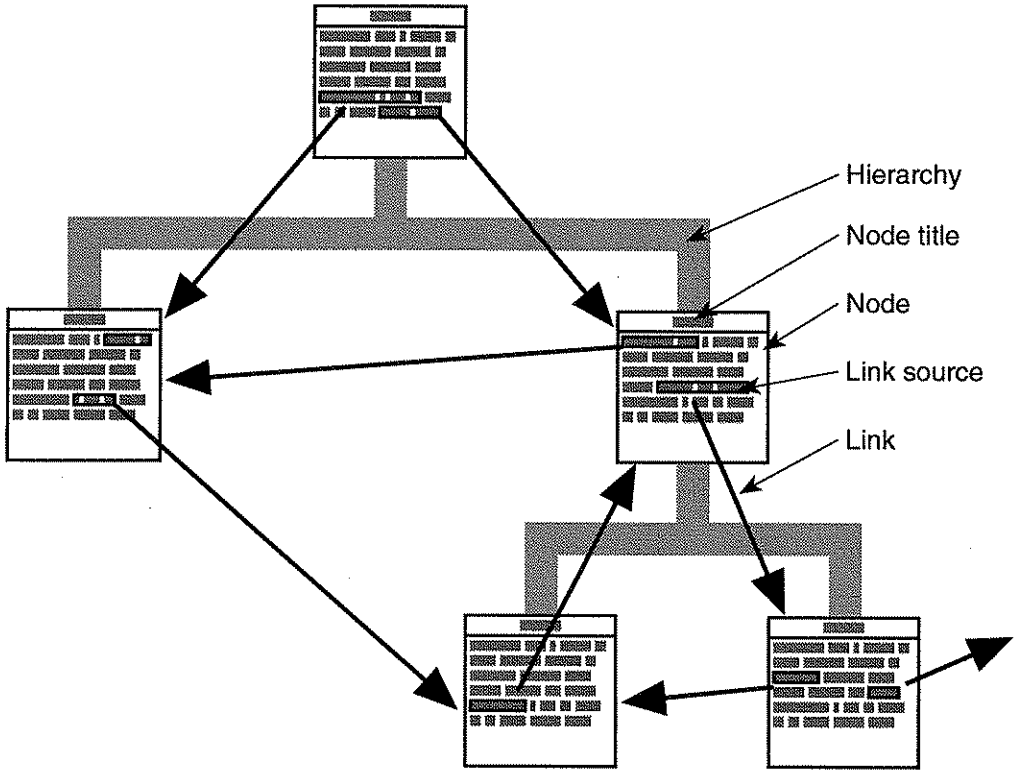

Figure 1: Schematic diagram showing how nodes of text are linked together in a network structure, and also in a hierarchical structure.

There is some method of selection, clicking the mouse for example, that allows the user to follow a link to the node it leads to. There is also the ability to display more than one node on the screen at a time in separate windows, and a 'map' of the hypertext can be shown, which indicates which nodes are linked to each other. A schematic diagram of such a system is shown in fig. 1.

The user can then read the text of any given node and, by clicking with the mouse pointer on the screen object that signifies the start of a link in the node, have other nodes displayed, which may then be read and used in the same way. In addition, nodes may be reached by selecting their representation on the 'map' of the hypertext, or by performing a search operation on the nodes' content.

3. DEFINING HYPERTEXT

3.1. The need for a definition

A definition of hypertext is needed for two reasons:

1. We need to know what its anatomy is and what concepts underlie it, in order that problems with its usage can be related to specific features of hypertext.
2. We need to know whether hypertext is one concept or many disjoint concepts, and if so, what the boundaries of those concepts are. This will enable us to associate particular problems with one or other of the forms of hypertext, whereas associating them with hypertext as a whole could result in confusion.

First the various purposes for which hypertexts are used will be looked at.

3.2. Uses for hypertext

This section summarises some of the tasks or activities for which hypertext systems have been built. Not all hypertext systems are designed for only one of these uses; some may combine support for several different uses in one system. They are used here to classify the different types of hypertext.

Browsing

This is the most general activity area of hypertext systems. Browsing describes the activity of navigating around a hypertext system, moving from node to node via the links or with the aid of a graph-type structure. Typically, the reader will read as much or as little of each node as necessary, and on the basis of what is read will decide what link to follow from that node.

Browsing is divisible into: (i) Purposeful browsing, and (ii) Aimless browsing.

'Purposeful browsing' describes the task of browsing when there is some specific piece of information in mind that is being searched for. An example of systems that are made primarily to support this type of browsing are help systems, in which the user browses through the hypertext structure in search to the answer to some problem.
'Aimless browsing' describes the sort of exploratory assimilation of knowledge that is so often spoken of in respect to hypertext systems. In this sort of use of hypertext, the user moves from node to node via the links between the nodes, choosing direction on the basis only of what takes their fancy, and without any specific goal in mind. However, there may still be a higher-level goal to this sort of browsing, for example the user may be trying to get an idea of what sort of things are held in the hypertext, or they may be trying to establish how the information is arranged in the hypertext, or may be pursuing a number of other similar goals.
Hypertext systems where this sort of information seeking is encouraged are such things as public information systems (e.g. Glasgow Online (Hardman, 1989)), and 'universal' systems, such as Xanadu (discussed in Conklin, 1987).

Instruction

In instruction-type hypertext interaction, some part of the choice of where to go next (seen in browsing) is taken away from the user, and they are led through a sequence of nodes, or at least encouraged to take some set path through the hypertext.
This sort of interaction is seen in CAL (Computer Aided Learning) hypertexts such as StrathTutor (Mayes, 1988), and in the 'Guided tours' of NoteCards (Begoray, 1990)

Problem exploration

In hypertexts used for problem exploration tasks (these include argumentation support systems and design rationale representation systems), rather than the hypertext being primarily a store of knowledge which is browsed through, the hypertext is the environment in which knowledge is built up. In this type of hypertext, the action of (often collaboratively) building the hypertext structure is as important as the ability to examine or browse the hypertext. The idea is then that the completed network of nodes constitutes a structured argument, or models a significant area of a particular problem (in the case of argumentation systems) or design space (in the case of design representation systems). For these purposes, the nodes and links are frequently of specialised types. For example the IBIS (Issue Based Information System) systems, rIBIS (Rein and Ellis, 1991) and gIBIS (Conklin and Begeman, 1988) ('real-time' and 'graphical' IBIS respectively) and the AAA system (Author's Argumentation Assistant (Schuler, 1990)) are designed to be systems for computer mediation of the

design process. The notion is that design is a conversation among "stakeholders" (designers, customers, etc.). These systems allow the creation and linking together of specialised node types such as, 'Position', 'Issue' and 'Argument' with link types that include 'respond-to', 'support', 'object-to', 'specialise', 'question', and 'be-suggested-by'. Using these, any stakeholder's position regarding the design or any part of the design and the processes by which they defend those positions, and how those positions relate to other stakeholders' positions can easily be encoded.

Typical in this sort of hypertext will be the prevalence of information that comments on other pieces of information in the hypertext. For example, in problem exploration or argumentation, where some issue is being explored, one node of information may be refuting the point made in another node (e.g. as in the gIBIS system (Conklin and Begeman, 1988)). Where such systems are intended to be used collaboratively over a distributed network (as in the rIBIS system (Rein and Ellis, 1991)) issues such as that of control-sharing need to be addressed.

Note-taking and writing

Many hypertext systems allow the user to author or customise hypertext structures. It is infrequent though that a hypertext addresses the issues associated with either writing a document 'from scratch' or writing a document with an end view for it to be produced as a linear text.

Trigg and Irish (1987) define writing as "consisting of a range of activities beyond simple text composition. These include among others: note-taking, organising and structuring, outlining, and maintaining references and bibliographies". They found that writers could use NoteCards as a writing tool if they had yet to determine the nature of the final product, or if they did not perceive the overhead of using it as being too great. Effectively this meant that writers were more ready to use NoteCards if the work involved using other pieces of work already in NoteCards. This suggests that hypertext systems are insular, rather than inherently difficult to use as writing tools.

Writing Environment (Smith et al, 1987, reported in Begoray, 1990) is a hypertext system built to enable the writing process to take advantage of the characteristics of hypertext systems. According to the cognitive model of writing used, the user will go through a three stage process:

1. Assemble potential ideas into network structure and explore relationships in the structure.
2. Impose super/ subordinate relations, levels of abstraction, sequencing, proportion and balance.

3. Describe ideas and relations between them in a linear sequence of "words, drawings or other explicit forms".

3.3. Related topics

There are several things which are conceptually close to hypertext. Looking at what makes these distinct from hypertext provides some insight into what hypertext is.

File systems and windowing systems

Although few people would claim that either windowing systems or file systems are hypertext, it is instructive to look at them to see how close they are to being hypertext. Doing so will enable us to see what makes hypertext distinct:

> "...several systems have some of the attributes of hypertext, but do not qualify. Window systems fall into this category; while window systems do have some of the interface functionality, and therefore some of the 'feel' of hypertext, window systems have no single underlying database, and therefore lack the database aspect of hypertext. File systems also do not qualify as hypertext; one could claim that a file system was a database, and that one moves among *nodes* (files) by simply invoking an editor with their names. However, to qualify as hypertext, a system must use a more sophisticated notion of links and must provide more machine support for its links than merely typing file names after a text editor prompt." (Conklin, 1987)

Conklin cites only the "lack of sophistication" of a file system's links as cause for it to not be considered a hypertext. File systems, and the iconic displays used to represent files in modern file systems are becoming ever more sophisticated, and the distinction between hypertext and file systems may soon be hard to make.

Semantic networks

There is an obvious parallel between hypertexts and semantic nets. They both represent knowledge in discrete portions in a network structure with each portion linked to those others to which it has some relationship. However it is important to make the distinction that whereas semantic networks are primarily designed for machine interpretability and as models of human memory, hypertexts are designed, or should be designed, for human interpretability. If semantic networks are an accurate model of human memory this may give some psychological justification for a similar network structure being employed in hypertext systems, but the differences in type of

knowledge stored and tasks carried out in the two fields make the comparison a difficult one to make.

Hypermedia

Whereas hypertext describes a network of nodes containing text and connected in some way by links, in hypermedia the content of the nodes can be any mixture of a variety of media. These media can include text, as in hypertext, as well as sound, pictures, animation or clips of video. Because it is now easy and cheap to present these other media and they are being increasingly used in hypertext systems, there is a blurring of the distinction between hypertext and hypermedia. Therefore, hypermedia is not studied as a separate area except where the extra use of media gives rise to problems. For example the technology for searching for a string in text is well-established, but there are far greater problems involved in searching for part of a picture, or for a piece of animation.

Public Information Systems

Public Information Systems are those systems on display in public places designed to give tourist information and the like. They are frequently simple hypertexts, but have two special features: Firstly, they must be usable by people who would never normally use a computer. This means that there is a much greater need than in other hypertext systems that problems associated with hypertext such as disorientation and cognitive overload must be minimised, even when this means reducing the functionality of the system. Disorientation is dealt with in some Public Information Systems by frequently returning the user to the 'front page', which also encourages short sessions (Bernstein, 1988). Secondly, session times must be kept short, "so that the next person can have a go".

An example of such a system is Glasgow Online (Hardman, 1989). It is based on HyperCard (Apple, 1987), uses mouse interaction only, and describes tourist information about Glasgow. Making it easy to use meant that it had to be carefully 'hand-made', and so the links are generally very domain and context-specific, and this is reflected in the 17 person years of authoring invested in it.

3.4. Definitions of hypertext

Hypertext is extremely hard to define. There are few, if any characteristics of a system which it is necessary that it have in order for it to be called 'hypertext', and there are many concepts apparent in systems that are called hypertext systems that are incompatible with each other. There is also confusion as to the precise meanings of many of the terms used when talking about hypertext.

We shall see that some of this lack of definition is due to the absence of a clear theoretical basis behind hypertext and because hypertext continues to be largely a technology driven field.

A few definitions from researchers in the field will give some different visions of what hypertext is before looking at it in more detail:

1. "A network representation of information is one of the defining characteristics of hypermedia" (Begoray, 1990)
2. "[The essential feature of hypertext systems is] machine-supported links" (Conklin, 1987)
3. "Windows on the screen are associated with objects in a database, and links are provided between these objects both graphically and in the database." (Conklin, 1987)
4. "[They are] methods of online information management and/or presentation in which textual documents are parsed into nodes. Usually each node contains a single concept, data element, idea or chunk of information. The nodes are connected to one another using links" (Mohageg, 1992)
5. "...true hypertext should also make users feel that they can move freely through the information according to their own needs" (Nielsen, 1989)
6. Other features cited as being 'defining features' of hypertext are that it should be computer based and involve reader participation (Begoray, 1990), that there should be an underlying database with a "coherent" link to that database (Conklin, 1987), and that there should be support for navigation (Halasz, 1988).

While these definitions are informative, there are hypertext systems that counter all of them to some extent. Therefore, they should be viewed with some caution and only as descriptive of subsets of the field of hypertext.

The first four definitions are limited in that they all define hypertext in terms of its components without addressing what concept might underlie hypertext. The fifth defines it in terms of what it is possible to do in a hypertext, but there are systems (for example, those that use 'guided tours', such as NoteCards (Trigg, 1988)) which explicitly prevent the user from navigating in this undirected way through hypertext systems.

Dimensions of hypertext

So that some means of describing hypertext systems can be built up that will for example, allow different systems to be compared with each other, various researchers have looked for dimensions along which hypertext systems might lie. Halasz (1988) gives 3 such dimensions. While these do not define hypertext on their own, they show some of the area over which hypertexts may vary, in particular at the authoring stage:

1. Scope: The size of expected information and user base. The scope will affect the underlying storage mechanisms, the user interface, and conventions for use of the hypertext.
2. Browsing vs. authoring: This dimension describes whether a system best facilitates browsing or authoring. 'Browsing' systems are carefully hand-crafted, usually with primitive authoring tools, and give the hypertext user a lot of rich information at a high authoring cost (cf. the 17 person-years spent making Glasgow Online (Hardman, 1989) discussed earlier). 'Authoring' systems on the other hand have well-developed tools for creating and modifying the system, but lack sophisticated information displays and support for anything other than very simple browsing.
3. Target task domain: Features and capabilities in the system often reflect the requirements of this domain (e.g. Neptune, discussed in (Conklin, 1987), built for software engineering emphasises versioning and node/ link attributes, but Intermedia (Yankelovich et al, 1988), built for multi-user interactive educational applications emphasises novel interactive displays and annotation facilities).

This last point is extremely important; because the uses of hypertext are so varied, and there is no predictive 'Theory of hypertext' that can be used to fine-tune the development of a hypertext, any given hypertext system's functionality must be based upon the requirements of the tasks to be carried out in that system.

Advantages of hypertext

Some insight into the thinking that underlies hypertext can be found from looking at the advantages claimed for hypertext by Conklin (1987). It is interesting that it is not made clear what it is (perhaps books, databases, etc.) that hypertext has these advantages over and for what purposes or tasks hypertext has these advantages. This point illustrates one of the difficulties faced when trying to define hypertext; its fields of application are poorly defined.

Broadly though, this list of hypertext's advantages suggests that it allows the user more control over the access to information.

- References from a document can be easily traced, by following links, and new references (essentially new links) can be easily created.
- Multiple schemes for organising information can be imposed on the same set of hypertext nodes.
- Global views of a document are available, similar to those provided by outliners.
- Customised documents can be formed by recording the order in which a certain set of nodes is to be traversed.
- Information is in modular units. The way hypertext operates, by having a single node able to be referenced from a variety of other nodes for a variety of reasons encourages the hypertext author to divide information up in this way.
- Because references (i.e. link anchors) are embedded in text, if the text is moved, the references remain consistent. This however implies that there exists some underlying model or description of the hypertext which has a description of where the link lies in the text.
- Both the functionality which allows the user to simultaneously follow several paths of enquiry, and that which allows several authors to collaborate over the construction of a document, with the document and comments about the document being interwoven, are cited as advantages. However, these seem to be advantages of certain specialised types of hypertext, and not relevant to all hypertext systems.

3.5. Conclusion

So, in conclusion, because of the diversity of hypertext systems, the most that can be said that encompasses ideas underlying all hypertext systems is that they are:

> Information systems in which the prerogative to structure and present information in a certain way, traditionally exercised by the 'author', is exercised in some part by the 'readers'. Hypertext systems allow the user to impose a structure (whether coherent and meaningful or not) on the text they read by their choice of what links they use.

The term 'hypertext' has been applied to so many things that its value and meaning have become considerably lessened since the time of its first usage[1]. This means that now, as well as calling some system 'hypertext', one must also specify for what purposes it is to be used, and what functionality it offers. The term 'hypertext' has become broad, so that there can not now be a 'universal hypertext' system that offers all the features now found in hypertext systems. An important need for the current work is that before any investigation is made into the characteristics of hypertext, the type of hypertext in question must be carefully defined.

4. HISTORY

The piece of work that is most often cited as the origin of the modern concept of hypertext is the article "As We May Think" by Vannevar Bush (Bush, 1945). Bush was the United States' director of the Office of Scientific Research and Development, and broadly, the article discusses the problem of turning America's wartime scientific effort towards peaceful goals. What needed to be done, he said, was to turn this effort towards tools that extended people's mental capabilities rather than their physical ones, in particular towards the end of improving access to the ever-increasing store of published knowledge. In introducing this point, he describes how the human mind accesses information, comparing it to the means of finding information in a filing system or library:

> "The human mind does not work that way. It operates by association. With one item in its grasp it snaps instantly to the next that is suggested by the association of thoughts in accordance with some intricate web of trails carried by the cells of the brain. It has other characteristics of course; trails that are not frequently followed are prone to fade, items are not fully permanent, memory is transitory. Yet the speed of action, the intricacy of trails, the detail of mental pictures, is awe-inspiring beyond all else in nature." (Bush, 1945)

Based on this, Bush puts forward the idea of a prosthetic support for human memory. He describes a hypothetical system he calls a 'Memex' which would allow such associative storing and linking of information. He deals in the world of microfilm and mechanical retrieval devices, but the ideas are still relevant. In this system, material can be freely entered (by photography) in whatever quantity the user may desire. It

[1]Even to the extent that the programming environment HyperCard (Apple, 1987) has frequently been called a hypertext (e.g. in Smith, 1988).

can also be browsed through, indexed alphabetically and annotated. Several projections of information can be viewed at the same time. Bush then introduces what he calls the 'essential feature' of the Memex, that of associating several items together. This involves having two pages of information presented and the user issuing some command that links them together. Many items can then be linked in a 'trail', and "when numerous items have then been linked to form a trail, they can be reviewed in turn, rapidly or slowly, by deflecting a lever, like that used for turning the pages of a book. It is exactly as though the physical items had been gathered together from widely separated sources and bound together to form a new book. It is more than this, for any item can be joined into numerous trails".

Bush rightly stresses the importance of access to information as being at least equal to the information itself. In his example, the shape/ structure of the trails through bodies of information are of great importance - "The inheritance from the master becomes, not only his additions to the world's record, but for his disciples the entire scaffolding by which they are erected"

5. COMPONENTS OF HYPERTEXT

This section examines hypertext from a technical viewpoint. Each of the types of component found in hypertext systems is examined.

5.1. Links

This section serves as an overview and introduction to links in hypertext. They are dealt with in more depth and from a more theoretical stance in the following chapter.

Functionality

Links have a dual role, called "representational" and "navigational" by Garzotto (1993). The representational role is to capture and represent relationships between pieces of information in the text, and the navigational role is to show paths down which the user may navigate.

On a more basic level, links are used in hypertext to connect together pieces of information. They can:

- connect a reference to a document to the document itself (Conklin, 1987)
- connect a comment on a document to that document (Conklin, 1987)
- connect documents together, and thus organise documents into a hierarchy or other structure (Conklin, 1987)
- connect text to its successor (Conklin, 1987)
- have actions associated with them (Bieber and Kimbrough, 1992)

- be inferred, rather than being explicitly represented in the hypertext (Bieber and Kimbrough, 1992)

Types of links

It is possible to formalise these different functions and arrive at a set of types of link, differentiated by the method of linking used.

Such a set has been described by DeRose (1989) who organises these types as a hierarchy (shown in fig. 2). Also Conklin (1987) describes links of two types, referential and organisational, and Mohageg (1992) talks about relational links, which share many properties of referential links. All of these are described below (only those types described by DeRose are shown in fig. 2 though):

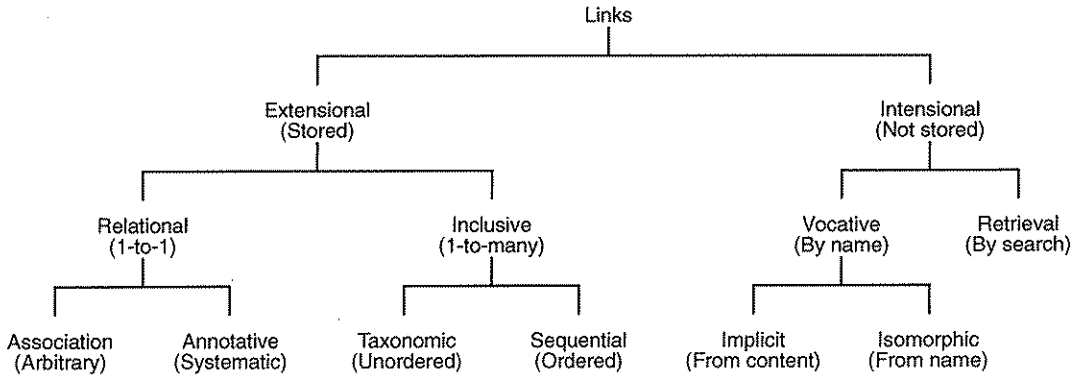

Figure 2: DeRose's hierarchy of link types. From DeRose (1989)

1. Extensional Links (stored)

   These are links that cannot be inferred by mechanisms in the hypertext from the content or structure of the hypertext, and so must be explicitly stored in the hypertext.

   Conklin calls these 'Referential' links: They are the most common form of link. They connect a 'reference' or a link source via a directional link (i.e. one that can only be traversed in one direction) to a 'referent', the link destination. The reference and referent can be either single points or regions of their respective nodes - most commonly the reference is a point and the referent is a region or an entire node. In this respect referential links are similar to links from text to footnotes.

   A subtype of these referential links are 'Semantically relational' links: These links are not common. To add semantic meaning to the connection, they have names or types associated with the link, rather than the link being a

'transparent' route from one node to another. They are therefore the same as referential links except that meaning is expected to be associated with the links; They are expected to say something about the relationship between the nodes they connect (e.g. that one node contradicts the other, or that one supports an argument made in the other). However a "significant amount of time and effort must be invested in creating relational links, especially given that no universally acceptable automated linking methods exist." (Mohageg, 1992). It is this kind of link that the work described in the rest of this thesis is largely concerned with. Mohageg's points sum up concisely why links of this type are not often used. When this type of link is used in a hypertext, sometimes a pre-defined taxonomy of links describing different semantic relations will be provided.

DeRose (1989) subdivides extensional links into 'Relational' and 'Inclusive' links:

1. Relational (1 to 1)

   These connect together two objects, and are either associative (i.e. they associate two things together) or annotational.

   Associative: Attach arbitrary pieces of documents. Usually typed. Garzotto (1993) describes these as 'application' links. They are set up by the author and denote arbitrary, domain dependent relationships. They may contain a link type or link name, a set of source and target entity types (specifying what can be linked to what), and a symmetry attribute ('symmetric' or 'asymmetric').

   Annotational: Annotational links connect pieces of text to information about that text, usually to one of a class of locations. Connections from text to information about the text are typical (e.g. every word could be linked to one of {noun, verb, adjective, etc.}). It is not necessarily predictable which of the class of locations a given piece of text will be linked to (unlike, for example, a link from a word to a definition of that word in a dictionary).

2. Inclusive (1 to many)

   They connect one location to many target locations and represent super/subordinate relationships.

   Conklin (1987) describes these as 'Organisational' links: They allow navigation of a structure. Their meaning is inseparable from the shape of the structure. For example if the structure of the hypertext was

hierarchical, there might be a link to navigate to the next higher level of the hierarchy.

They can be divided into 'sequential' and 'taxonomic' links:

Sequential: These allow the text to be presented in a linear form when needed. They require specialised display methods; often these links will be triggered automatically, for example, as the user scrolls, to give the appearance of the 'document'.

Taxonomic: These lead to multiple target locations but do not impose order on them. They are "generally lists of properties with some document element", "one may associate examples of some literary phenomena with commentary about it" (DeRose, 1989).

2. Intensional Links (not stored)

These follow from the structure and content of the documents they link, and so need not be individually stored; for example 'keyword' links. Garzotto (1993) describes a form of structural links, derived from the structure of the hypertext, and connecting components belonging to the same entity ("Up", "Down", "Next sibling", "Root", etc.). He also describes 'perspective' links, which again are derived and connect together the different units that correspond to the same component. In Garzotto's system, HDM (Garzotto, 1993) these interconnect units within a single perspective.

DeRose subdivides intensional links into vocative and retrieval links:

1. Vocative (by name)

These invoke a particular document element by name. They are either implicit, or isomorphic.

Implicit vocative links exists because the link's target's name appears within the content of the source document. E.g. a dictionary definition for a word, available from every occurrence of that word in the source document.

Isomorphic vocative links exist because the link's target's name is an element name in the source document (rather than content). They define structure among large structures of elements, usually documents, e.g. "The Bible" might be mentioned in the source document. There are of course many documents all called "The Bible" with slightly different structures and contents. This reference however would still be recognised as a reference to some abstract meta-document called "The Bible".

2. Retrieval (by search)

   These links invoke a search for something in the space of documents available. In doing this they may require any attribute to be searched on, such as name, content or structure.

Other terms used in describing links are:

- Source and Destination: Describes the regions of the nodes that a link is connected to, where each region may be part or all of a node, or information external to the hypertext.
- Target: The representation of the source and destination on the display. They may be represented by a form of highlighting or a different colour, etc.
- Anchor: Either a source or destination. This term is generally used to distinguish the part of the link that interacts with the node from that which links the two nodes.

Link design issues

This section summarises some design issues that need to be taken into consideration when considering link usability. From (Begoray, 1990):

- How the link should be activated, (e.g.: by mouse click, touchscreen etc....)
- How the link should be represented in the node (i.e. what the target looks like)
- The size of the link source and destination. Each of these can be an entire node, a portion of a node, or a single word or a phrase in a node. (Usually the source of a link is a single word or phrase, and the destination is a whole node.)
- How long the link takes to be activated and take the reader to the link's destination. Begoray (1990) and Conklin (1987) argue that the shortest possible link activation time should be sought, which agrees with findings from Akscyn et al (1988), who add the proviso that response times should not be too short (Their findings were that response times of around 0.05s to 0.1s sometimes caused subjects not to notice the transition from one node to another).

5.2. Nodes

A node is a discrete block of editable media which may or may not have a title. A node is usually displayed on its own in a window (Begoray, 1990) and expresses a "single concept or idea" (Conklin, 1987). It is important that this is the case, because in written text, it does not seriously inconvenience the reader if a concept is not neatly contained

in a section or paragraph. However, because of the effort in getting from one node to another, and because one can often only see one node at a time, adjacent nodes in hypertext are more separate than adjacent pieces of written text. Therefore, if a concept partially dealt with in one node is continued in another, there is a greater possibility of the user not discovering this second node than in an equivalent situation where paper-based text is being used.

Modularisation

The question of how to modularise a linear text into nodes deeply affects the usability of hypertext systems. By imposing the structure of a set of discrete nodes on a text the hypertext author is saying a lot about that text. Often hypertext systems have used the constraints of the technology they are implemented on as a basis for the modularisation process, resulting in this criticism from Conklin (1987): "People don't think in terms of "screenfulls"; they think in terms of ideas, facts and evidence".

Typed nodes

'Typed nodes' can ease the modularisation process by taking advantage of structure that may be in what is to be represented; e.g. in Conklin's (1987) ISAAC system where a node to represent a design decision is needed, there is a node with an internal structure consisting of a set of slots: (Issue, Set of alternatives, Analysis, Commitment). Each of these can be filled in during the design argumentation process.

Additionally, some systems support special node types to perform unusual tasks, such as to help manage the structure of a hypermedia graph. For example in NoteCards there are special cards which will present graphical representations of a selection of other cards (Begoray, 1990).

Granularity

A hypertext will exist at some point on a fine-grained/ coarse-grained dimension, and will generally lie between having a large number of small nodes or a small number of large nodes (Begoray, 1990). As the node size decreases, connectivity increases, and with this, Begoray suggests, user disorientation increases.

Node presentation

The size of a node can either be tied to that of the window it's in, or it can be bigger and able to be scrolled within the window. Similarly, simultaneous multiple node presentation may be possible through the use of multiple windows. These presentation issues will depend on the platform the hypertext is implemented on.

5.3. Hierarchies

As well as the network of links connecting nodes together, it is common for the nodes to be organised in a hierarchical structure. This easily allows support for a 'summarise' or 'abstraction' relationship between nodes at different levels of the hierarchy. This improves navigation and reduces disorientation, although because the construction of a hierarchy forces the author to sort the nodes into a number of sets, introduces categorisation problems (i.e. hierarchies won't necessarily split things up in the way best suited to the users' needs, or may be appropriate for one task but not for another).

Mohageg (1992) studied the effects of different linking structures in hypertext on the efficiency of performing simple fact-gathering tasks in hypertext systems. He compared linear, hierarchical and network linking structures. The linear linking structure allowed subjects only to move through the nodes in any section of the hypertext in a certain order; the hierarchical structure forced subjects to navigate a hierarchy to get through the hypertext, and the network structure used a network of links based on keyword searches. He concluded that "hierarchical linking structures should be implemented for most hypertext (or text-intensive) databases used for information retrieval". He found that in terms of task completion time, the hierarchical links were superior to relational links derived from keyword searches. He does not discount the usefulness of relational links, but stresses that it would be unwise to build a hypertext without 'organisational' (i.e. hierarchical) links.

5.4. Graphs

A 'graph' is a visual representation of a collection of linked nodes, and a 'web' is a subset of the nodes in a graph, if the whole graph cannot be shown (Begoray, 1990). Webs and graphs are navigation tools, as well as being informative (i.e. they are not just maps, usually one can select a node in the graph to go to that node). Therefore, when designing a web or graph structure, thought must be taken as to how it can be used for navigation, and whether additional information needs to be displayed that would not be needed if the web or graph were only being used as a map.

Additionally, if multiple structures are present in the same hypertext network (i.e. hierarchical and network structures), some decision must be made as to what structure(s) to show, and how best to show them.

A number of things can be used to define what subset of a graph should be made into a web; the web could be just the nodes most local to the current one; the web could be the result of a query, either a search on the text of the nodes, or on anything else,

including aspects of the structure of the hypertext; the link taxonomy could be used to filter out a web (e.g. "Make a web, only including nodes linked by links of this type"); mechanisms to filter out nodes based on their attributes could also be used (Begoray, 1990).

Problems with webs and graphs include:

- Webs and graphs become extremely complex, and hard to represent clearly as the hypertext system grows beyond the browser's capacity (This problem has arisen in NoteCards (Halasz, 1988) and Thoth-II (Collier, 1987)). Also, the web can only be as good as the structure of the hypertext system it represents; as de Young (1990) says "if a hypertext is a densely connected unstructured graph, no presentation of the mess is going to clean it up or make it conceptually easier to understand".
- The reader has difficulty knowing which node on the web or graph is the node that he or she is currently reading.
- The reader does not know how the web that is displayed fits into the global hypertext structure.

Some options for the design of hypertext webs which may alleviate these problems are provided by Utting and Yankelovich (1989):

1. Assume 'geographical' knowledge of graph.
   That is, assume that the user has a model of the structure of the graph. This is only really possible for spatial location data, where the nodes on a graph represent physical locations and are arranged in the same manner on the graph as their physical counterparts. Also the graph is not easily updatable.
2. Display as a hierarchy
   Although a hierarchy can be helpful, and is easy to visualise, depending on the data being displayed in the graph, it may not be useful.
3. Centre web on current node
   An example of this approach is the 'spider' web used in Thoth-II (Collier, 1987). The user starts off being shown a central node with all the nodes connected to it also shown. When the user clicks on a different node, all the links connected to that node are shown. New instantiations of all connected nodes are made to avoid links crossing each other. This approach has the advantage being able to show clearly what nodes are connected to the current one, although the map quickly gets very big, and there is not necessarily any correspondence between the relationships of nodes on the presentations of two webs, each of which has a different node at the centre.

4. Display global or semiglobal views, as in gIBIS (Conklin and Begeman, 1988) or NoteCards (Halasz, 1988).

   These are graphical browsers and allow user repositioning of nodes to aid understanding. They also allow zooming, and multiple levels of detail to be shown. They provide an idea of the size and level of connectivity of the whole network.

5. Display 'filtered' browsers.

   This is a means of simplifying the web (and thus overcoming some of their inherent presentation difficulties) by creating a new web based on the result of applying some filter to the complete web. For example, in NoteCards (Halasz, 1988) and Neptune (discussed in Conklin, 1987) new webs can be created based on the results of queries.

6. Temporal methods

   This includes backtracking (e.g. HyperCard (Apple, 1987), FRESS (Feiner and van Dam, 1981) and Guide (Begoray, 1990)) and history lists. Also the 'timeline' of EDS (discussed in Utting and Yankelovich, 1989), which displays a timechart showing miniatures of all the nodes you visited, and when. This is a bit more sophisticated in NoteCards (Halasz, 1988) where a history list is provided, and any node on this list can be "opened up" into a minibrowser to show its neighbours - visited nodes are annotated in these browsers.

5.5. Other hypertext components

These are various other components and terms used in hypertext, from Bernstein (1988), Conklin (1987), and Begoray (1990):

- Path: The route a user has taken traversing the links and nodes.
- Perspective: This is the perspective the user acquires of the information as a result of their path.
- Bookmark : A personal marker put in place by the user of a hypertext to enable them to return to that point.
- Thumb tabs: An author-generated marker, to allow easy access to 'key' nodes.
- Margin notes : A note or annotation made by the user.
- Breadcrumbs : A record of where a user has been, to enable them to tell whether they have visited a particular node before.

- Ports: These are used in the Boxer system (described in Conklin, 1987). This system contains no links, but connects nodes (called 'boxes') together with 'ports', which allow the user to view part of the destination node. They are distinct from links in that they reflect changes in the destination node.

Indexes

Indexes are typically nodes containing many links either specially compiled or generated automatically. Their special features are that firstly the user is able to suppose that everything of interest in the hypertext system is referred to in the index, and secondly that the list of links is usually ordered alphabetically. They suffer from the same problems as ordinary links and for example, do not alleviate problems of identity (see section 6.5 of this chapter), so if the user does not know how to refer to what they want or does not know how the hypertext system's author may have referred to it, an index may be of little help. Problems of cognitive overload may also arise if the index items' names are not sufficiently descriptive and the user feels the need to follow up several of them. Indexes have been shown (Hammond & Allinson, 1989) to improve users' knowledge of the hypertext as a whole and, because a good index should cover everything in the hypertext, they allow users a better understanding of how much of the hypertext they have read than simple links do.

Guided tours and tabletops

These are both features of the NoteCards system (Halasz, 1988).

Guided tours are similar to the 'trails' described by Bush (1945). In the 'tour' the user can only move linearly through a subset of nodes in the hypertext. By constructing a 'tour', the hypertext author helps lift some of the burden from the user of keeping track of where they are in what may be a very large, highly connected hypertext.

The original idea is enhanced in NoteCards, "The stops on a NoteCards tour are sets of cards in the hypertext network arranged on the screen according to a particular layout [called a 'tabletop']. This allows the spatial juxtaposition of multiple sources of information in addition to the sequential information inherent in the tour. The tour itself is a fully-fledged node in the hypertext network" (Trigg, 1988). The 'tabletop' captures the parameters of all the nodes currently displayed on screen and is modifiable by the user.

5.6. Summary

Although there is some variety of hypertext components, it can be seen that the chief of these are the node and the link, and that the rest largely play a support role. Nodes

and links are more formalised in some areas than others, and the language used to describe nodes and links is not yet well defined.

It is also interesting that there is little integration of hypertext components; while some may cite a certain node type as a solution to a certain problem, and a certain link type as a solution to another, there appears to be no attempt to solve wide-ranging problems with hypertext through solutions that require certain attributes of both links and nodes. This indicates a lack of any model of hypertext, or means of describing hypertext on an abstract level. Indeed, it seems that all one can describe are components of hypertext, rather than hypertext as a whole.

6. PROBLEMS

6.1. Lack of a high level abstraction

Currently there is no "language of hypertext" to describe the structure and organisation of the information in a hypertext at a high level. Neither is there any theory of hypertext design and use. These two things would provide some principles for hypertext construction and the ability to see past the links and nodes and other technology of a typical hypertext. Thus, an abstraction of the hypertext would be available from which usability predictions could be made, and which would allow computer-aided manipulation of the hypertext's structure, either to better facilitate the task in hand, or to allow compatibility with other hypertexts. Linked to this first problem, and possibly due to it, is the lack of hypertext standards, and hence compatibility between hypertexts.

Currently, hypertexts are largely technological solutions to the variety of problems to which they are cited as being answers. Either they are merely *ad hoc* constructions of text and links and nodes, or else only small areas of the hypertext's construction are supported by theory or empirical evidence. Although hypertext is concerned with the structure and interrelationships in information, there is at present no coherent way to describe either of these things in a way that is useful as an abstraction for any of the various forms of hypertext.

Marchionini and Shneiderman (1988) and Hara et al (1991) put this concisely, the first talking about the lack of understanding about how hypertexts are used, and the second about the lack of understanding of hypertext links:

> Marchionini and Shneiderman (1988) identify "Three pillars of Hypertext research": Information retrieval, Interface design and Cognitive science. Of Cognitive Science, they say: "We lack a clear definition, much less understanding, of the interactions among an

information seekers' knowledge about a problem, past experience in searching for information, and knowledge for possible sources of information. Furthermore, since any system that supports information-seeking must structure knowledge to make it accessible, the systems themselves affect how users think when using them."

"The regularisation of associative links, which are essential to information captured in hypertext as a network or as a loop structure, still remains a problem. A theoretical and analytical evaluation of this problem is necessary for both conceptual and physical designs." Hara et al (1991)

However, hypertext is still a young field and such problems should not be disheartening[2]. Marchionini and Shneiderman (1988) sum this up: "Since hypertext systems have a brief history of application, we have sparse evidence for their effectiveness, let alone proven principles to guide design"

Effects of this lack of a coherent 'theory of hypertext' can be seen:

- Hypertext does not cope well with inferred/ implicit linking. E.g. If you type text into an hypertext which contains a keyword, it should inferentially link that keyword (Bieber and Kimbrough, 1992). This has been addressed to an extent in (Kaplan and Maarek, 1990), using "dynamically determined semantic interrelationships". This method automatically links together parts of the hypertext based on how the hypertext is used, and on lexical analysis of the text.
- Hypertext systems are very insular; it is very difficult to bring anything in to work on the data in the hypertext (Brown, 1988).
- Evidence suggests that hypertext links are often put in place without thought as to how they will be used or how useful they will be. In addition, hypertext systems share the problem with other methods of information retrieval that "the user does not know if the failure to find an answer is due to poor formulation of the query, an incomplete search, or the absence of the information in the database"(Campagnoni and Ehrlich, 1989). In hypertext systems this is compounded by the fact that because of the lack of a methodology for linking and a common understanding of what links mean, the user will not necessarily be able to understand how best to perform a search, let alone why the search failed.

[2]Hypertext's current state is analogous to "programming languages in the fifties" (Brown, 1988)

This last point, the lack of any formalism for linking, is seen in the work of Landow (1987): "The experience of ... users with *Context32* clearly demonstrates that simply linking one text to another in some cases fails to achieve the expected benefits of a hypertext system and even alienates the user".

Landow further reports subjects not being able to understand why something was at the end of a link and thus (most importantly) "they resented the presence of the link". He then hypothesises:

1. Hypertext links condition the user to expect purposeful, important relationships between linked material
2. The emphasis on linking materials in hypertext stimulates and encourages habits of relational thinking in the user.
3. Therefore, since hypertext systems predispose users to expect such significant relationships among files, those files that disappoint expectation appear particularly incoherent and insignificant.

And it is this that is the worst result of the lack of hypertext theory; if links are found not to be useful they will be ignored; if we are going to build hypertexts with links in them, they must be useful. As Landow says, "Books permit the student user to avoid apparently non-significant materials ... but hypermedia systems, whose linkages suggest that the user will encounter significant relationships between materials make ignoring such materials more difficult. They force the user to confront relationality - or its absence" (Landow, 1987).

6.2. Cognitive overload

Conklin (1987) describes this as the 'Cognitive overhead' of working in hypertext as opposed to working with paper, and gives an example of how it might arise with someone writing notes into their hypertext:

> "Suppose you are writing about X, and a related thought about Y comes to mind, and seems important enough to capture. Ideally hypertext allows you to simply "press a button" (using some mouse or keyboard action) and a new, empty hypertext window pops onto the screen. You record Y in this new window, then you press another button, the Y window disappears, and you are in the X window right where you were when Y occurred to you."
>
> "Unfortunately, the situation is a bit more complex than this scenario implies. If Y has just occurred to you, it may still be hazy and tentative; the smallest interruption could cause you to lose it.

> Coming up with a good word or short phrase to summarise Y may not be easy. You have to consider not only what will be descriptive, but also what will be suggestive for the reader when he encounters the link to Y within X. In addition you must determine whether you should name the link to Y to suggest the contents of Y or to show Y's relationship to X. ...Beyond that you must also consider whether you have provided sufficient links to Y before returning to work on X. Perhaps there are better ways to link Y to the network of thoughts than at the point in X where Y came to mind" (Conklin, 1987)

Of course not all hypertext systems may work quite like this, but this example shows the cognitive overhead that exists in this case. This example shows cognitive overload in hypertext authoring. There are other areas of hypertext usage in which analogous problems can be seen; for example, when reading from a hypertext system and following a path of enquiry, one may come across another path which seems useful. It is then necessary to make some decision, either to take up this new path and risk losing track of the old one or being unable to find it again, or to ignore it.

So it is this added power that the hypertext reader has over the paper reader, to order their viewing of the chunks of text according to their own needs, cited earlier as an advantage of hypertext (in section 3.4), that can cause problems. Jones (1987) writes about this power's benefits and penalties:

> "Current hypertext efforts have focused on the development of tools giving users direct control over the formation and traversal of links connecting units of information in a network structure. Such tools place considerable power and a considerable burden in the hands of the users."
>
> "Hypertext would appear to have selection benefits... Given the expression of one idea, writers are no longer required to choose which of several competing ideas to express next - each can be linked to the current idea. However the malleability/ extensibility of hypertext is a double-edged sword ... from the reader's perspective some selection may be better than none, but too much selection may be worse. Do readers want to be repeatedly faced with tens, perhaps hundreds or alternatives?" (Jones, 1987)

6.3. Disorientation

Conklin (1987) talked of disorientation as one of the major problem areas of hypertext. He divided this into two smaller areas. These are the problems of knowing (i) where you are and (ii) how to get to some other point in the hypertext which you believe or hope exists. There is also the user's feeling of not knowing what is in the immediate vicinity of the current node. Elm and Woods (1985) describe this as: "The user not having a clear conception of the relationships within the system, ... finding it difficult to decide where to look next in the system."

Many of the reported problems of disorientation in hypertext centre on this last point, the user not having an model of the system as a whole, either in terms of its content or structure, and solutions to the disorientation problem seek to address this.

The most simple solution to the problem is to provide hypertext users with an explicit model of the system in the form of a graph structure[3]. However the use of large graphs brings all their associated problems (as seen in section 5.4), and may even add to the users' disorientation. This type of 'large, loosely structured graph' may itself cause disorientation. The reason for this is that it is usually not possible to show everything in a single browser, and the more complex the structures of browsers are the more likely it is that users will lose themselves in this navigational support system (Conklin, 1987 and McKnight et al, 1989).

Other approaches have concentrated on augmenting the simple map of a hypertext with extra features. Akscyn et al (1988) suggest problems with disorientation can be reduced by:

(i) Encouraging the author to structure their hypertext system hierarchically.

(ii) Providing special navigation commands to go directly to 'key' locations.

(iii) Showing the user how to easily return from where they have just come from.

(iv) Making the nodes fewer, but more complex. This may be valid, although avoids the problem of disorientation by reducing the amount of navigation the user has to do.

(v) Keeping response times short. This encourages users to follow links, by making link following 'cheap' in term of the time wasted if the link led to a node the user did not want to go to.

[3]And this assumes that it is possible to represent the document graphically.

Abstraction

Botafogo and Shneiderman (1991) examine various solutions to the problem of disorientation in hypertext, summarising that (i) multiple windows can help in only a localised way, (ii) maps become too complex when hypertexts have lots of nodes, and (iii) paths are hard to author and maintain.

They suggest a technique for providing abstractions of the hypertext, in order to make it a more manageable entity, and thus less of a cause of disorientation. This technique is aggregation, an aggregate being defined as "a set of distinct concepts that, taken together, form a more abstract concept" (Botafogo and Shneiderman, 1991).

To use these, first a metric for the compactness (or interconnectedness) of a hypertext is needed. This metric is rated on a scale between 0 and 1, so a completely disconnected set of nodes would score 0, and a set of nodes in which every node was connected to every other would score 1. Then semantic clusters are identified, where a semantic cluster is a subgraph which has a compactness greater than that of the whole graph. These clusters can then be treated and viewed as separate entities, giving the hypertext user an abstraction of the hypertext.

This technique will only work well if the hypertext is sensibly structured to start with however, with a greater density of links among semantically related items, and an even density of links across the hypertext. Additionally, the effect of index and reference nodes must be discounted.

6.4. Authoring/ Text-to-hypertext conversion

Thomas and Mital (1992) give the example of a law firm, in which each worker has a set of proforma documents and precedents, each one appropriate for a particular need. While any one lawyer may know where they have stored certain documents, as soon as more than one lawyer needs to gain access to the same documents, the way in which those documents are filed needs to be formalised. Similarly in the case of hypertext, the hypertext author is filing pieces of text into different nodes, and in order that people other than the author can use the hypertext, there needs to be some methodology behind the authoring process.

Text-to-hypertext conversion can be done either manually, or can be automated. Rada (1989) discusses text-to-hypertext conversion, first automatically by exploiting cues in the original text's mark-up language... "Several commercial companies now have computer systems for translating text into hypertext - these systems exploit the standard mark-up commands in the text. Taking a text and converting it into a hypertext with a rich non-hierarchical network structure is, however very difficult

because the re-enactment of the early authoring steps must occur" (Rada, 1989). Whether or not any of the authoring done by the original author of the text has to be re-done, it is certainly the case that if a hypertext is going to display a structure that reflects the organisation of ideas in the original text, the work involved in the conversion of the original text to hypertext will not be trivial, as it implies some understanding of the aims and structure of the text.

There are broadly two steps in manually converting a text to hypertext, dividing the text up into nodes, and establishing links between the nodes. The first step involves deciding on what grounds one wants to count text as belonging in one constituent or another, and the second involves deciding why a user would want to travel from one node to another. Neither step is trivial, and both demand that the author know the purposes for which the hypertext will be used.

Rada (1992) differentiates between what he calls first order and second order hypertexts. These largely correspond to the automatically and manually created hypertexts described above; first order hypertexts reflect the mark-up language (Outline headings, also bibliographic references, footnotes, etc.); second order hypertexts derive from the structure of the text but contain a structure not explicit in the text's mark-up.

As can be imagined, creating a large hypertext manually is a great deal of work (e.g. Hardman, 1989). It is done because methodologies for automatically creating hypertexts still lack the power of manual creation, and are intolerant of badly composed texts. Manual creation is however very costly, and means that very few large hypertexts are made at all. As Smeaton (1992) says, "One of the serious problems of hypertext is the overhead of the hypertext authoring process".

6.5. Identity problems

Identity problems concern knowing what something is, and particularly in hypertext, knowing the meaning of something from its description.

Problems of identity will occur when linking together things in separate hypertext systems, created in different contexts for different needs. The question is how to know whether the two different documents' description of a given thing are in fact the same thing. Each description depends on the document's author, and so to understand a hypertext, the reader needs to know something of the rhetorical framework the hypertext was constructed in. "Suppose you wanted to find the same A in world X as in world Y. You would need a way of recognising that A and B were the same. They could only be the same if those worlds were made up of the same (sorts of)

individuals" (Stein and Sheridan, 1990). For example, to find the same page number of an article in two databases - it only works if both articles use page numbering in the same way. In Stein's study, the four main problems they found in the domain they looked at (searching across two scientific literature databases) were:

1. Lack of definition of an 'article'.
   E.g. Where two articles are only interpretable together (as in an article and a rebuttal from different people) are they one work or two?
2. Authorship across time and space.
   E.g. for one article written by a committee, one database, which did not allow many people to share authorship, had nothing in the author field, and the other had put the name of the committee in the author field.
3. Individuation across and within categories.
   Are category boundaries drawn in the same way in the different 'worlds'? In one of the databases, a group authored article's title contained the name of the authoring committee, in the other one this was in the 'author' field. This implies that there are things in one database that could not count as the same thing in the other.

The particular examples given here may not apply directly to hypertext. However, such problems are extremely relevant to hypertext. The failure of understanding comes when reference is made to something whose meaning cannot be understood because that thing was created in a context in which the meanings of things differ from the current context. In a hypertext setting this could occur when a link is made to something in another hypertext system, when the two hypertext systems are authored by different authors for different purposes.

6.6. Interface problems

Problems with hypertext interfaces are not qualitatively different from those seen in interfaces in other application domains. However, hypertext does have special features that exacerbate these problems. Also, because hypertext is so often touted as being easy to use and providing so much, "people seem to expect more of hypermedia interfaces than they do of conventional interfaces". (Waterworth and Chignell, 1989).
McKnight et al (1989) identifies four problems areas commonly associated with hypertext interfaces:

1. Reading from screens That is, the difficulty and speed penalty associated with reading from screens as opposed to reading from paper. This may not be such an issue as it once was; the bulk of the experimental work done in

this area was done on monochrome, character-based terminals whereas hypertext is now only rarely seen on anything other than large, high-resolution colour graphics terminals.

2. Reader behaviour Readers get different kinds of information from a physical journal than an electronic one, and are likely to do things with it that are hard to transfer to an electronic form (flick through it, scan the contents, feel it to see how carefully it's produced, etc.). Generally, paper-based text allows a greater range of action, and permits actions to be carried out more readily. For example, readers like to annotate their personal copy of a text, something that can be done in many hypertexts, but is likely to be easier on paper.
3. Presentation These issues deal with how the text is presented on the screen
   - Display size. Generally, increasing the size of the screen will increase the amount of information that can be presented to the user, which may, depending on the task to be performed, improve performance. For example, if a user was working with many hypertext documents at once, a large screen which allowed simultaneous presentation of all these documents would be an advantage.
   - Manipulation facilities. Text can be presented as a single scrolling unit, or separate nodes. Manipulating text with scrolling is liable to weaken any visual memory readers establish for the location of items in the text. Node based manipulation supports memory for the position of items in a page, but is detrimental for memory of the order of those items in a document. The literature is unclear; various experiments have been done, but are inconclusive. Monk et al (1988) reported that readers performed better with a 'scrolling browser' than a hypertext browser. However the tasks given in this study were to answer questions about various aspects of a computer program which was presented in one of the two browsers. It may be that the tasks involved in reading and understanding this text type are not suited to a hypertext-style of interaction.
4. Input devices A mouse is by far the most common input device for hypertext, although some systems (e.g. Hyperties (Plaisant, 1989)) uses cursor keys. Milner (1988) concluded that although a mouse was generally better than other means (e.g. cursor keys, function keys, joystick), there were

also task-related elements (e.g. a touchscreen might be better if only low-resolution input was required).

5. Non-text issues By this is meant such issues as icon design and the use of colour. Little can be said in respect to these except that guidelines are lacking.
6. Response rates It has been suggested that if response times are as short as possible, this will aid browsing and reduce disorientation (Campagnoni and Ehrlich, 1989), although Akscyn et al (1988) found that users needed the system to have a minimum response time in order that they notice the transition from one node to another.
7. Metaphor The 'travel' metaphor is the one most often used in hypertext, either 'go it alone', or 'guided tour' (i.e. either user or system controlled). The metaphor of the paper book has also been used. However this is largely shaped by the paper-making and publishing industries, and there is no reason why an electronic book should necessarily be similar in function to a paper book. Little research has been done into the effectiveness of or comparison between metaphors in hypertext.

6.7. Summary

The problems identified in hypertext are typically not due to the lack of some technical component. Indeed, as is seen with some types of link, the problem can be the presence of some ill-conceived part of the hypertext which alienates the user.

The problems are not only complex, but often interrelated. For example, it might be thought that a user's disorientation could be solved by giving them more information, but this brings with it the danger of adding to that user's cognitive burden and making the hypertext system unusably complex.

One of the elements that seems to be common to many of the problems discussed is the lack of a large-scale model to describe hypertext, or some means of abstracting away from the technology of the hypertext. The interactions between, for example, the user, the user's task, the text type, the linking structures, the node structures, and the user's difficulties in finding what they want are too complex to allow their problems to be addressed individually, yet it is difficult at present to do anything else.

7. RESEARCH TOPICS IN HYPERTEXT

This section covers some research topics in hypertext. The topics here do not reflect all the areas in which research is being carried out, but merely highlight some areas that are pertinent to this thesis.

7.1. Hypertext Models

This section summarises approaches to hypertext which base the development of a hypertext on a coherent model.

Reasons for the development of a design model for hypertext applications, given by Garzotto (1993) are:

- Improvement of communication between analyst/ end user, analyst/ system designer, system designer/ implementor, because there is a common language used to specify the application.
- Development of design methodologies and rhetorical styles. A model of hypertext would provide a framework in which methodologies could be discussed at a high level.
- Reusability. The 'hypertext semantics' (linking structures, specialised node types, etc.) would be reusable.
- Provision of consistent and predictable reading environments. This consistency would be within, as well as between applications, and would benefit readers.
- Use by design tools. With a design model, tools can be built to construct hypertext systems.

A key part of such models is the use of object-oriented principles for describing and using hypertext components. This results in the ability to create 'open' systems, that work as part of an existing computing environment. For example the HAM (Hypertext Abstract Machine, Campbell, 1988) model "treats hypermedia nodes, links, webs and graphs as data objects, and provides operations for creating, modifying, storing and accessing them. The specifics of the user interface to those objects is left up to the application using HAM as its base" (Begoray, 1990).

Similarly, Proxhy (Process Oriented eXtensible HYpertext architecture, Kacmar, 1991) is also modular, and incorporates a user's current computing environment. The links between things "can be applied to any application environment, provided the application's objects have unique identities" (Kacmar, 1991). So object-oriented graphics, for example could be incorporated.

Proxhy allows existing applications to incorporate hypertext at minimal cost, and it is 'open', so data can be shared across applications. It is typical in being made up of layers:

- Communications Protocol layer: Message routers/ object definition table - defines classes and subclasses of object hierarchy/ inheritance mechanism.

- Hypertext layer: Anchor and link processes and associated communicating processes. "An anchor object may be responding to the query of an application object to locate alternate versions while at the same time the corresponding link object is responding to a structural search request by another application".
- Application layer: 1 or more applications on different machines.
- Back-end layer: File management, data management.

These models describe modular, rather than monolithic hypertext systems. The link and node types used are simple, but accommodating in terms of the types of information they can link.

7.2. Halasz's 7 issues

Halasz (1988) described "7 issues for the next generation of hypermedia systems". This work is still relevant, and while it should not be taken as determining the functionality of future hypertexts, it does point the way to some of the things missing from present-day hypertext systems.

1. Search and query in hypermedia networks

This issue is designed to address the problems that while navigation is a defining feature of hypermedia systems, it causes problems when working with large networks.

Halasz suggests that a query-based access mechanism may alleviate this problem, which can perform searches on the content of both links and nodes, and searches on the structure of the hypermedia for subnetworks that match a pattern. This implies the need for a representation of the hypertext.

2. Composites - augmenting the basic node and link model

This includes the ability for nodes to include others, either by inclusion or reference, and the ability for a node to represent a cluster of others. These ideas are similar to those of Botafogo and Shneiderman (1991) about aggregation, discussed in section 6.3 of this chapter.

3. Virtual structures for dealing with changing information

The problem addressed here is that strict titling, segmentation and filing constraints associated with authoring hypertext mean that information represented often does not match the users' representation. Also, networks are usually hard to change; Halasz's response is that some means of describing the structures amongst the components of a hypertext is needed. So, rather than specifying the content of links or nodes, describe

the components, and have them dynamically assigned, so that they change every time the information changes. This approach is addressed by Kaplan and Maarek (1990) who use linking structures based on an analysis of the text and how the text is used (summarised earlier in section 6.1).

4. Computation in (over) hypermedia networks

"The integration of hypermedia and AI technology is an interesting direction to explore. In many ways hypermedia and knowledge-based systems are a natural fit. In particular, at a high level of abstraction, hypermedia, frame-based systems, and object based systems present nearly identical data models. Each of these technologies is based around the idea of types, slotted entities that form a network structure via inter-entity references". The difference, Halasz says, is that "Unlike expert systems for example, hypermedia systems do not include inference engines that actively derive new information and enter it into the network".

To an extent however, this shortcoming of hypertext is subsumed by others; for example, if the 'virtual structures' spoken of above were implemented, automatic manipulation of the hypertext could follow relatively easily.

5. Versioning

Versioning, Halasz says, is not dealt with in a lot of hypermedia systems. Providing a branched version history for all entities in a hypermedia network raises difficulties because of the network of dependencies necessary as a result of the network of links between nodes.

6. Support for collaborative work

For concurrent work, standard read/ write locks are inappropriate; one person may want to modify a node's text; another may want to modify its link placings. The control of who is allowed to do what needs to be fine grained.

7. Extensibility and tailoribility

"The generic nature of hypermedia systems is both a blessing and a curse. It is a blessing because it allows hypermedia to be useful in a wide variety of task domains and user populations. It is a curse because generic hypermedia is not particularly well suited to any particular task or style of use"

This point echoes what was said earlier in this chapter about the variety of hypertext systems with conflicting functionality. It is not useful to speak of a "generic" hypertext system, because such a thing cannot exist, in the sense of a hypertext systems that combines all the things that current hypertext systems do. The point Halasz makes

emphasises the need for the task requirements for a hypertext to be well-defined in advance.

8. CONCLUSION

This chapter should have introduced and given the reader an overview of hypertext. This chapter has also demonstrated that hypertext is currently suffering from a vagueness of definition.

Several different types of hypertext have been explained in this chapter, together with a variety of hypertext components. In the rest of this thesis a simple model of hypertext will be assumed, much like the example hypertext given at the beginning of this chapter (Section 2). This will allow the linking structures of hypertext systems to be concentrated on without confusion.

Problems associated with hypertext were shown in this chapter to be due to the inadequacy of current models of hypertext. For example, the problem of 'disorientation' arises from users not knowing what is accessible to them in the hypertext system, and 'cognitive overload' from users having to keep track of the information in the hypertext system as well as information about how to get to certain places in the system and routes from one point to another. Both of these indicate that the users lack understanding of how the hypertext system is structured. The hypothesis behind this thesis is that some of these problems can be alleviated by more explicitly showing the structure of the hypertext through the addition of more information to the links. To do this, it is necessary to not only find some information that can be shown to help hypertext users, but also to at least prepare the way for extending this work into a means of modelling links in hypertext that would take into account all the user, task and system issues surrounding hypertext linking.

Hypertext can be seen as text, divided up over nodes, with one or more methods for structuring and presenting those nodes imposed on them. The primary method for both imposing structure and for navigating around the text is that of links between the nodes of text, but there are others such as hierarchies, graphs, indexes, maps, browsers, and guided tours. The tasks for which people use hypertext systems, often reflected in different patterns of behaviour within the hypertext system, are more or less supported by each of these different means of structuring information. For example Hammond and Allinson (1989) showed that maps, indexes and guided tours are superior to links for allowing users to get an overview of the hypertext and an understanding of how much of the hypertext they have read. Then there are usability problems associated with hypertext, principally those of disorientation and cognitive

overload (discussed in section 6) which are more or less alleviated by each of these additional features of hypertext.

One of the symptoms by which these problems can be recognised is that they force the user to adopt a browsing strategy when they might rather be purposefully searching for information. Cognitive overload forces users to have to consider following more routes in the hypertext than they would like to and to browse to look for links they have forgotten the location of, and disorientation makes users have to look around to find anything of interest because they do not know what information is accessible. A feature common to these usability problems is that they demonstrate the user's lack of a conceptual model of the hypertext, which might allow them to be able to predict where information would be found.

An important perspective on hypertext arises from this and from the work in this chapter. This is that hypertext is a challenge not so much a piece of information retrieval technology, but as a knowledge representation scheme. If the scheme by which hypertext represents knowledge and the interrelationships between pieces of information was more readily understandable, then the users' ability to predict where information could be found in the hypertext and to remember the location of information would be increased, lessening hypertext's information retrieval problems. This concurs with the definition of hypertext reached in section 3.5 where one of the defining characteristics given to hypertext was that it allowed the user to structure and present information in a certain way, according to their needs.

The purpose of this thesis is to assess the feasibility of this perspective. It seeks to alleviate the problems associated with access to information in hypertext by enriching the way hypertext functions as a knowledge representation scheme. In the following chapters, theoretical, and then empirical approaches to testing the feasibility of this hypothesis are explored.

3: Links

"Is your journey really necessary?" (World War II Railway poster)

1. INTRODUCTION

An overview of links was given in the previous chapter. Links were divided into a number of types by DeRose and Conklin and in this chapter the type of link that DeRose (1989) calls 'associative' and Conklin (1987) calls 'referential' is examined. These names refer to the same thing. In this chapter they will be referred to by the more usual name of 'relational links'.

The dual role of links was also discussed, that is, the need for them to provide information about the relationships in the hypertext and to allow navigation through the hypertext. The former of these two functions is stressed here.

The type of link being examined expresses some relationship between the pieces of information it links. This chapter examines what characteristics a relationship between two pieces of information has, and how these characteristics relate to the links of hypertext systems.

This chapter then, examines how relational links can best communicate the local structure of a hypertext and how such links or sets of such links might be developed.

2. THE ROLE OF LINKS

Part of the definition of hypertext given in the previous chapter was that they allow the user to impose a structure on the text they read by their choice of what links they use.

From this, a possible reason for problems with hypertext and in particular the 'Disorientation' problems dealt with in the previous chapter, is that the hypertext system is failing to effectively support the user in showing them different possible structurings of the text.

Links are not the *raison d'être* of hypertext systems, in the sense that what the user wants is not a link, but some information, or a greater understanding of some topic; links are a tool. As de Young says, "users often do not need to think in terms of links or navigation. They just access the information they need." (de Young, 1990). So a hypertext system that forces the user to concentrate on understanding the process of navigation is not meeting the user's needs.

There is a need for links in hypertext to communicate the semantic structure of the hypertext system. Links in hypertext have a dual role, to (a) allow navigation, and to (b) show the semantic structure of the hypertext. To support (b) without (a) would be useless because to allow access to information is the main purpose of a hypertext system. Therefore it is essential that a link allows the user to travel through a hypertext. However, to only support navigation through the hypertext, without providing means for the user to learn the structure of the hypertext is not enough. This is often done though, and as was shown, leads to navigation and disorientation problems.

The question that arises from this asks what information should the links in a hypertext represent beyond that which merely facilitates navigation, and then how can this best be done.[4] A link between two or more things expresses some information about the relationship between them (even if it is only "These things are linked"). What this thesis is concerned with is what the most useful information is for a link to express for the purposes of the hypertext user.

Work on navigation difficulties in hypertext covered in the previous chapter gives some indication of what information it is that links are failing to provide. The rest of this chapter refines this and looks at what means are available to express this information.

3. THE NEED FOR LINK-TYPE RELATIONSHIPS

Throughout this discussion, relationships are taken as being separate from links. A relationship shows how two or more pieces of information are related, and is an abstract thing; a link is an artefact in a hypertext system, which may or may not represent a relationship.

In the majority of hypertext systems, hypertext links have been put in place with greater emphasis being placed on their role as a navigational tool than their role as describing relationships between pieces of information. This can be inferred by the lack of explicit information a link gives about the relationship between the information in two nodes. In the extreme case, such links denote only that two nodes are connected, and say nothing about the connection. Of course the hypertext user may make some implication just from the knowledge that a piece of information is linked to something else, but this may be incorrect or inappropriate.

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[4]It should first be remembered that this study is looking only at the role that the links play in hypertext; While the information provided by other features of hypertext may be important, no other hypertext tool is as fundamental as the link.

Landow (1987) criticises this form of linking, arguing that "simply linking one text to another in some cases fails to achieve the expected benefits of a hypertext system and even alienates the user". This alienation of the user arises from (i) the user being unable to see why two things are related or, (ii) having followed a link, discovering that what they expected to find at the end of the link is not there. Both of these point to the need for explicit representation of the meaning of the link.

For the same reasons as Landow, de Young also criticises arbitrarily linking one thing to another; "a great strength of general hypertext systems is that any piece of information in the system can be linked to any other piece of information. However, this freedom and flexibility can also prove to be a great weakness"(de Young, 1990).

Links which contain some information about the meaning of the link besides that of what nodes they connect, could be used to provide the hypertext user with more information. The link could be used to tell the user, reading information in one node, what may be expected at another node, by communicating the relationship between that node and the current one. An alternative method would be for a link to tell the user explicitly what is in another node, rather than what the relationship between the nodes is, but this would make the link's function more like that of an index. A hypertext system could be built as an index or a network of indexes, but this ignores one of the principal attractions of hypertext, that is has the potential to show pieces of information as parts of an interrelated network. Using a hypertext system can also be a dynamic process, and the user may not necessarily be looking for a single piece of information, or the answer to a specific question, but rather will have their information needs best met by a combination of pieces of information from various points in the system (A discussion of the appropriateness of different hypertext components for different information-gathering tasks is in chapter 6). For this to work properly, the hypertext system must show the user how the possible linkages in the hypertext system lead away from where the user currently is, and this can only be done by showing the relationships between the information to be found and what the user already knows. Links in hypertext systems that perform this role shall be referred to as 'typed links' - that is, hypertext links that are differentiable from each other by having different types, each type representing a different kind of relationship.

De Young (1990) points at why typed links might be useful, arguing that "if the structures [i.e. the links] are a reflection of the process or task for which the hypertext system is used, the user who is familiar with the task is already familiar with the structures as part of his or her task knowledge" (de Young, 1990).

There are several ways in which typed links may be implemented in hypertext. The first and simplest solution (from an authoring point of view) is to allow the creation of typed links on an *ad hoc* basis, leaving the choice of what relationship will be presented to the user up to the hypertext's author. DeRose (1989) warns against this, saying that it will lead to a profusion of link types, with (particularly in systems with multiple authors) many names for the same thing, and similar names for distinct things. Trigg (1983) also warns against having a limitless set of link types. He cites three practical reasons against it: (i) The system will eventually contain unmanageably many link types, (ii) Readers will misunderstand what other link type authors meant when choosing names for their link types, and (iii) if there is any understanding of a link type's semantics by the system, this will have to be explained by its author. He also posits that it is unlikely that new link types are being regularly discovered and so there is little need for the facility to be able to create new link types.

Another solution is to have a defined set of relationships created with the aim of allowing some specific reading or authoring tasks perhaps in only a single information domain. The sets of relationships used in Textnet (Trigg, 1986) and gIBIS (Conklin and Begeman, 1988) are examples of this approach, where each link type can help to fulfil only a narrow range of tasks. This domain-dependence of the hypertext design may also be reflected in the range of node types available, and in the ways in which certain link types may be used between certain node types. This approach, the building of domain specific hypertext systems or hypertext authoring systems, undoubtedly has application, and indeed has been found to be useful in the areas for which the approach has been tried. However such specialisation runs counter to Bush's (1945) original idea of the Memex, from which the modern notion of hypertext comes, as the "World's record", a single store of all human knowledge, or Wells' ambitious 'World Encyclopaedia':

> "[A reader would] ... without any great toil or difficulty, find in clear understandable language, and kept up to date, the ruling concepts of our social order, the outlines and main particulars in all fields of knowledge, an exact and reasonably detailed picture of our universe, a general history of the world, and if by any chance he wanted to pursue a question into its ultimate detail, a trustworthy and complete system of reference to primary sources of knowledge."
> Wells (1938)

A 'World Encyclopaedia' designed as a set of separate hypertext systems each containing a separate set of domain-dependent link types would place an intolerable

load on the user, who would have to learn to use any unfamiliar system encountered. In addition, by altering the methods needed to use hypertext systems based on their information domain, navigation between hypertext systems is made harder, since the boundary between any two information domains will be explicit, and will entail the user altering their behaviour.

Therefore, what this thesis aims to investigate is the potential of a set of domain-independent link types for hypertext systems. Such links would avoid (i) the lack of flexibility and power in the very simple navigational links, (ii) the scope for confusion inherent in complex links defined on an *ad hoc* basis and the (iii) the learning and authoring load of navigation tools that are newly designed for each system. What is being looked for are links with recognisable meanings across users, and also with meanings that are consistent across information domains.

The next two sections (Section 4 "Relationships in data" and section 5 "Relationships from linguistics") looks at what a relationship is from a theoretical perspective and what the attributes of relationships are. Section 4 looks at the attributes of relationships from the perspective of databases. It examines how these relationships' attributes are used in implementations of hypertext links, and how hypertexts fail to take advantage of the potential expressiveness of links. Section 5 examines the models of relationships established by work in linguistics, and examines the usefulness of these approaches for the current work.

4. RELATIONSHIPS IN DATA

Kent (1978) discusses what a relationship between two information objects is. From his analysis of these we can see what limits are put upon the expressiveness of hypertext links in their current form, and in what ways they might be extended.

Kent's work does not give indications as to what relationship may be best for one purpose or another, nor does it deal specifically with the domain of relationships to be used in hypertext links. However, what it does do is to discuss relationships on a general level and provide a scheme of the dimensions along which relationships may vary. From this work it is possible to see how lacking in any formal structure most hypertext linking methodologies are.

In this section each of the attributes of relationships that Kent (1978) describes is summarised, and its relevance to hypertext links discussed.

4.1. Degree

'Degree' defines the number of objects involved in a relationship, or more accurately, the number of categories of objects, for example "employ" might be of degree 2

(employer, employee) even though there may be many employees. Kent gives, as an example of a relationship of degree 3, a supplier(1) who ships a part(2) to a certain warehouse(3).

Relationships of a degree greater than 2 can also be seen in such things as Toulmin argument structures (Toulmin, 1958), discussed below. No hypertext system seems to have used anything other than relationships of degree 2 in their links.

As an example, there could be a 'definition' link in a hypertext which linked words to their definitions. The link would be of degree 2, even though one word might be linked to several different definitions in different dictionaries.

4.2. Domain

This defines the classes of things that may occur at points in the relationship (e.g. one may "own" many categories of things). It defines, for a particular relationship, what things may be related.

This attribute of relationships when applied to hypertext raises the issue of node types. In most hypertext systems, nodes are not typed, but where they are used it can be seen that a distinction is made between them similar to that made between domains in Kent's analysis. Several hypertext systems use typed nodes, and gIBIS (Conklin and Begeman, 1988) uses the idea of domain in specifying what node types may be linked by what link types (see figure 3 below).

In the hypertext system Thoth-II (Collier, 1987) there are special links and node types which may be connected to each other in specified ways. "[Nodes] do not contain information. Instead, they are connected to zero or more pieces of text by a special type of link ['text links']. These pieces of text are connected back to the nodes by another type of link ['lexical links']. A third type of link connects nodes to each other ['value links']. Each node has a lexicon of keywords which can be used for searching." (Collier, 1987) These specialised link types have defined domains, but at a syntactic level. A more useful extension of the idea of domains into hypertext would be at the semantic level, which would allow the hypertext user to make inferences about what node type is at the end of a link based on the link's type. This is seen to an extent in gIBIS, below.

4.3. Role

'Role' describes the function of each domain in the relationship (e.g. "Owner" and "Owned"). This allows a relationships to be specified as a set of roles, rather than having to describe how each domain fits into the relationship. It is also useful for

making distinctions when a domain has to take on several roles (e.g. both "manager" and "managed" may be of the domain "employees").

This is a refinement on the idea of domains. In fig. 3 below, the node types used in gIBIS (Conklin and Begeman, 1988) are shown, together with which of the link types may be used between any of them. It can be seen that an 'Issue' in gIBIS can be linked by the 'questions' or 'is-suggested-by' link types. An issue may therefore be simultaneously a 'questioner' and a 'suggester'. If these roles had to be specified separately within the 'Issue' node, it would make clearer what it was about the issue that was performing each role.

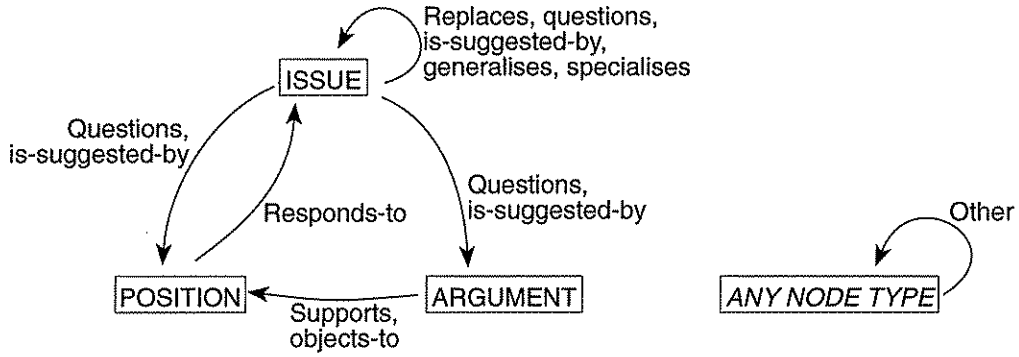


Figure 3. The allowed links between node types in gIBIS (from Conklin and Begeman, 1988)

4.4. Complexity

Kent characterises a relationship as being simple if it is a one-to-one mapping, and complex if it is a one-to-many mapping. Thus, for some relationships whether it is simple or complex will depend on the direction in which the relationship is being traversed.

Complexity is relevant to some hypertext links, in particular those which DeRose (1989) calls 'Inclusive' and Conklin (1987) calls 'Organisational' (See the description of these link types in the previous chapter). These links allow navigation of hierarchical structures or taxonomies, and represent super/ subordinate relationships. The concepts of complexity and simplicity are relevant to such links and must be encoded most obviously because the screen representation of complex links will differ from that of simple links.

4.5. Self-relation

Self-relation occurs when something is connected to itself by a certain relationship. Three possibilities exist; the relationship is not meaningful between items in the same

category; the relationship is meaningful between different items in the same category; individual items may be related to themselves with that relationship type.

Some self-relation constraints are present in gIBIS, and are implied in the diagram above. However, it is not specified whether individual things may be related to themselves.

Self-relation is a useful concept because, although it could be treated as a special case of a normal relationship, if for example a node was linked to itself for some purpose, this may affect how the link is presented on screen. Also for example, one might disallow self-relation for a link that implied connection between levels of a hierarchy.

4.6. Optionality

This determines whether or not each thing that can exist on either side of a relationship has to be part of a relationship (e.g. every employee has to be employed, and therefore must be connected by the "employs" relation).

It is implicit in any hypertext system that every node is accessible, and therefore must be linked by some sort of link. So, in the very simple sorts of hypertext where there is only one link type, it is implied that everything that can be linked must be part of a relationship of the type embodied in that link type. If this type of link were to be given a name it might be "associated with", or some other general term. This tells the user nothing that is not already known, that is, that the two nodes are linked.

In hypertext systems with a variety of link types, usually not everything that can be linked by a certain link type has to be. Exceptions are seen in specialised link types, such as links to indexes. SuperBook (Egan et al, 1989) provides implicit links which index every occurrence of every word in the text, so in this case, everything that can be linked by an 'index' link is linked.

4.7. Transitivity

Whether, for some relationship, if X is related to Y and Y is related to Z, X is related to Z.

Usually in hypertext a link is pointing at some other node related to but different from the current one, and because of this, transitive links are not likely to be used. Only if a link, for example, implied that two nodes were on exactly the same subject might it be transitive.

In this case, transitivity could be used as a tool to extend the number of nodes accessible from the current node by automatically linking those nodes that logically should be linked to the node. Attributes such as transitivity, because of their logical nature, allow simple computer manipulation of links.

4.8. Symmetry and anti-symmetry

A relationship is symmetrical if X is related to Y with a certain relationship *because* Y is related to X with that same relationship. Symmetrical relations make the concept of "degree" slightly ambiguous, as there are no longer distinct roles (e.g. To say that A and B are married is the same as saying B and A are married). With some relationships if X is related to Y, Y cannot be related to X by the same relationship (e.g. the relationship "is-the-father-of"). These Kent calls anti-symmetric.

In hypertext, examples of symmetrical links might be "is-on-the-same-subject-as", or "contradicts", whereas "continues-on-from" might be anti-symmetric.

On the subject of link directionality, Trigg (1983) differentiates between the physical and semantic direction of a link. Its physical direction "defines the manner in which readers are expected (by the link's author) to follow the link". A link's semantic direction can be seen in this example: "A refutation link connecting A and B can be read "A refutes B" and thus the semantic direction is from A to B". The semantic direction can differ from the physical direction; "the refuting author may wish readers to see refutation A only after having read the refuted node B".

4.9. Implication

A relationships may be implied by the existence of one or more others (e.g. "is-the-employer-of" implies "is-the-employee-of" in the reverse direction).

In Trigg's (1983) taxonomy of link types, he provides several pairs of links one of which implies the existence of the other. For example 'summarisation' and 'detail'; to say that "A is a summary of B" implies "B provides detail on A".

4.10. Subset

A relationship may be a subset of a more general type of relation. There may then be a taxonomy of relationship types with relationships inheriting features from those 'higher up' the taxonomy.

Relation Element Theory, described by Chaffin and Herrman (1986) demonstrates this concept, which it uses as a means to make the relationships more comprehensible: "The theory assumes that relations are defined by simpler relations, called relation elements, and that comprehension of a relation between two words involves determining whether the words possess the elements of the relation."(Herrman and Chaffin, 1986).

Trigg (1983) classifies the hypertext system Textnet's link types into a hierarchy, where only the leaf nodes of the hierarchy are used as links. For example, the links are

divided up into 'normal' and 'commentary' links; one of the divisions of 'commentary' links is 'style', and one of the links in this grouping is 'S-Unimaginative'.

4.11. Restrictions

There may be a number of restrictions in addition to those implied by other attributes of the relations; for example, the number of items that may be related to another by a given relationship type may be restricted. In hypertext this could be done to make screen presentation possible, and to avoid burdening users with too many links at once.

4.12. Attributes and relationships of relationships

This covers information about the relationship, and might, in a hypertext system include such things as when it was established, by whom, and so on.

In some systems links may be attached to links, as well as nodes (for example, the 'commentary' links in Trigg's (1983) Textnet, mentioned above, may be attached to links, so that one may comment on the placement of a certain link. In general though in hypertext systems, links contain only a very limited amount of information. More information, such as pointers to indexes of links, might allow the user to search for certain links, or for certain patterns of structure in the hypertext. For example, in the same way that the arrangement of relationships in a Toulmin argument structure (Toulmin, 1958) make it identifiable as a certain sort of structured argument, some other arrangement of relationships and nodes may be recognisable as an explanation, for example, or a summary (see section 6 for a discussion of this).

4.13. Name

Relationships can also be nameless or for binary relations, have one or two names[5]. No name is necessary when the two domains being related are distinct and there is only one relationship type possible between them (or there is a convention for choosing a default relation). Having one name is conventional, although does not fit in with actual language usage except for symmetrical relationships. Two names is better in this respect (e.g. "employ" and "employed") and could eliminate the need for role names.

Relationship names are extremely important in hypertext as they are generally the only way the user has of determining the function or meaning of the link. Therefore the use of link names in hypertext shall now be examined in some depth.

[5]Relationships of a degree greater than 2 may have more than 2 names.

Link names in hypertext

Often in hypertext systems a link can appear to have a name but will in fact have no name. This can occur in two ways. Either the name is not really the name of the link but the name of the node that the link leads to, in which case the link indicates only that one may go to that node by activating the link. Alternatively, the link is indicated by a highlighted (or in some other way emphasised) piece of text in a node, in which case the link indicates only that that piece of text is linked to something else. The links then have nothing but their navigation function - the ability to take the user's attention to another node. In this case their functionality is less well defined than that of the navigational tools (e.g. "Go back...", "Next") which at least indicate to the user what they do. This type of hypertext includes Intermedia (Yankelovich et al, 1988) and Hyperties (Plaisant, 1989). Also there are those hypertext systems that incorporate AI methods or sophisticated text-searching methods to produce this type of 'nameless' links by inference, or in response to user requests. These include SuperBook (Egan et al, 1989) which indexes every occurrence of every word in the text and Grolier's Electronic Encyclopaedia (discussed in Marchionini and Shneiderman, 1988) which produces results of queries as alphabetically sorted lists which can be used as links.

Then there are those hypertext systems with links that embody domain-specific relations which have names distinct from the text. 'Domain specific' means here that the link types are especially pertinent to the subject matter of the hypertext; these links then would not necessarily work in any other hypertext. Hypertexts of this type are Thoth-II (Collier, 1987), Glasgow Online (described in Hardman, 1989), and MacWeb (Nanard & Nanard, 1991). For example in the Dickens' House Museum Library hypertext system (Phelan, 1992) which is written in Guide 3.0, one is able to follow links with names like "Oliver Twist", and then "Criticism", to arrive at a summary of the criticism of that novel.

Finally there are hypertext systems with sets of named domain-independent links. 'Domain independent' means that the same set of links may be used, irrespective of the content of the hypertext. The best-known hypertext system built of this type is the now relatively old Textnet (Trigg, 1983). Examples of the link types used in Trigg's work include "Summarisation", "Continuation", a selection of citation links such as "C-Source", "C-credit", and various types of 'commentary' links, such as "Pt-redherring" (commenting on a point), "S-rambling" (commenting on style). Although these are all links with single names, because some of these links are in two opposite forms, these could be expressed as one single link with two names (e.g. One such pair of link names is "Summarisation/ Detail").

Domain-independent links also occur in the work by Thomas and Mital (1992). This work is interesting, because although the work takes place in the domain of working with legal documentation, the links used are not specific to that domain. The five types of links provided are: (1) Usually follows, (2) Alternative, (3) Inconsistent, (4) Necessary part, (5) Refers. Another interesting feature is their hypertext system's ability to take simple actions dependent on the type of link encountered. For example, if the user looks at a text unit which is the source of some 'usually follows' links, the hypertext system will display the names of the target text units.

4.14. Summary

This section has looked at hypertext links, assessing them with attributes normally given to database links. In databases it is necessary for the links to be rigidly defined, and so performing this sort of examination of hypertext links provides both a framework for looking at hypertext link's functionality, and terms to describe aspects of hypertext links.

In addition, the analysis of the scope of the relationships discussed here shows the areas of meaning that relationships can express which are not used in hypertext links. There are three important ways in which this section can provide enhancements for hypertext links:

1. By showing the ways in which information about the things that they link can be codified (with attributes such as "degree", domain", and "role"). Because something is then formalised about what the link is connected to, there may be at least some element of the meaning the author intended by the link that can be manipulated or acted upon by tools in the hypertext (for example, search tools).
2. The functionality that links can have can be extended (with attributes such as "transitivity", "symmetry", and "implication"). These allow links to be related to other links and for links to imply the presence of more links.
3. The discussion of link's names in this section stresses the importance of the notion of a relationship name that is independent of what that link connects.

5. RELATIONSHIPS FROM LINGUISTICS

The approaches examined here were looked at to see if any existing model of text organisation could provide a start in formulating a set of domain-independent link-types for hypertext systems. In fact no single one of them was found suitable, but ideas from them were used, as will be seen.

From linguistics the literature on Rhetorical Structure Theory (Mann and Thompson, 1988) and Relation Element Theory (Herrman and Chaffin, 1986) provide analytical models of texts. These models describe how texts might be structured and inter-related, opening up the possibility that it might be possible to describe the structure of hypertexts with similar models. Story Grammars and work on Expectation provide data on how users of text form models of texts.

5.1. Rhetorical Structure Theory (RST)

RST is described in (Mann and Thompson, 1988). It is a descriptive theory of a major aspect of the organisation of natural texts.

It has been studied in several fields:

1. As a means to describe relations among clauses in a text. In particular this enables one to see whether clauses are related in either the lexical or grammatical structure of the text.
2. As an analytical tool for texts and narrative discourse
3. As a means for investigating relational propositions - unstated but inferable propositions that arise from the structure of a text but which contribute to a text's coherence.

There are 4 defined types of object:

- Relations: Made up of constraints on two non-overlapping text spans, and an effect that the relationship has. Thus, when analysing a text with RST, it might be presumed that the author's purpose in putting in place a piece of text that causes an RST relationship to be made was to produce that effect.
- Schema: A small group of text spans and relations in specified patterns, analogous to a grammatical rule.
- Schema applications: These are schemata when they are applied to a text. Conventions are specified regarding how the schemata can differ in actual application in a text from their definitions.
- Structural analyses: A structural analysis of a text is a set of schema applications such that a set of constraints hold which in effect cause the analysis to be in the form of a tree.

It describes texts in terms of a set of relations and 'schemata' which indicate how these relations should be used. However its weakness for the purposes of hypertext linking is that it is only a descriptive, analytical model of text, rather than reflecting how readers of text might structure a text. The set of relationships it uses are shown in table 1.

Circumstance	Antithesis and Concession
Solutionhood	Antithesis
Elaboration	Concession
Background	Condition and Otherwise
Enablement and Motivation	Condition
Enablement	Otherwise
Motivation	Interpretation and Evaluation
Evidence and Justify	Interpretation
Evidence	Evaluation
Justify	Restatement and Summary
Relations of Cause	Restatement
Volitional cause	Summary
Non-volitional cause	Other relations
Volitional result	Sequence
Non-Volitional result	Contrast
Purpose	

Table 1. RST Relationships from (Mann & Thompson, 1988)

It has been used by Gotel (1990) as a framework on which to base a set of hypertext links. In this piece of work, RST relations were modified by "regrouping and redefining them" (Gotel, 1990; page 74), and split up into "Subject matter based" and "Presentation based" groups. They were used primarily because RST was the most recent model of text structures (Gotel, 1990; page 73), and because they were used only as a tool to further the main aim of her work, to test whether a methodology for text to hypertext conversion could be developed, it is difficult to draw conclusions from their use in this situation.

5.2. Relation Element Theory (RET)

Relation Element Theory has as a basic assumption that "relations are defined by simpler relations, called relation elements" (Herrman and Chaffin, 1986). The set of relationships it uses is shown in table 2 and the elements that make up those relationships in table 3.

This seems attractive for a model of hypertext links because of the fairly mechanical way it treats relationships. It is backed up by experimental work in (Chaffin and Herrman, 1984, and Herrman and Chaffin, 1986). However, the set of relationships being used was *a priori*, culled from linguistics work, and designed to be used between pairs of words, rather than larger pieces of information.

Relation families	*Example*	*Relation elements*
I. Contrast		
Contrary	old-young, happy-sad	Dim(Bip(Sym),Cont)
Contradictory	alive-dead, male-female	Dim(Bip(Sym),Dis)
Reverse	attack-defend, buy-sell	Dim(Bip,Dich,Vec)
Directional	front-back, left-right	Dim(Bip, Dich,Top)
Incompatible	happy-morbid, frank-hypocritical	Dim(Bip)
Asymmetrical contrary	hot-cool, dry-moist	Dim(Bip,Cont)
Psuedoantonym	popular-shy, believe-deny	Dim(Bip,Con)
Attribute similar	rake-fork, painting-movie	Int(Over(Att,Dis))
II. Similars		
Synonymity	car-auto, buy-purchase	Int(Inc(Bil))
Dimensional similar	smile-laugh, annoy-torment	Int(Over),Dim(Unip)
Necessary attribute	bachelor-unmarried, tower-high	Int(Over(Att,Poss))
Invited attribute	food-tasty, cut-knife	Inc,Poss,Con
Action subordinate	talk-lecture, cook-fry	Int(Inc(Unil))
III. Class inclusion		
Perceptual subordinate	animal-horse, flower-rose	Int(Inc(Unil))
Functional subordinate	furniture-chair, tool-hammer	Int(Inc(Unil))
State subordinate	disease-polio, emotion-fear	Int(Inc(Unil))
Activity subordinate	game-chess, crime-theft	Int(Inc(Unil))
Geographical subordinate	state-New Jersey, country-Russia	Int(Inc(Unil))
Place	Germany-Hamburg, Asia-China	Inc(Partive(Poss,Loc))
IV. Case relations		
Agent-action	artist-paint, dog-bark	Evt(Act,Obj)
Agent-instrument	farmer-tractor, soldier-gun	Evt(Agent,Inst)
Agent-object	baker-bread, sculptor-clay	Evt(Agent,Obj)
Agent-recipient	sit-chair, hunt-prey	Evt(Act,Obj)
Action-instrument	cut-knife, drink-cup	Evt(Act,Inst)
V. Part-whole		
Functional object	engine-car, tree-leaf	Inc(Partive(Attach,Comp,Prop,Poss))
Collection	forest-tree, fleet-ship	Inc(Partive(Homo,Prop,Poss))
Group	choir-singer, faculty-professor	Inc(Partive(Homo,Prop,Poss,Soc))
Ingredient	table-wood, pizza-cheese	Inc(Partive(Comp,Prop,Poss,Loc))
Functional location	kitchen-stove, house-dining room	Inc(Partive(Attach,Comp,Prop,Poss))
Organisation	college-admissions, army-corps	Inc(Partive(Attach,Comp,Prop,Poss, Soc))
Measure	mile-yard, hour-minute	Inc(Partive(Homo))

Table 2. The list of semantic relations from Relation Element Theory (Chaffin & Herrman, 1986) with examples and relation elements.

Relation elements		*Description*
I. Elements of intensional force		
Denotative	Den	W_i and W_j share denotative meaning
Connotative	Con	W_i connotes W_j
II. Dimensional elements		
Dimension	Dim	W_i and W_j share a single dimension
Unilateral position	Unip	W_i and W_j are on same side of midpoint
Bilateral position	Bip	W_i and W_j are on opposite sides of midpoint
Symmetrical position	Sym	W_i and W_j are equidistant from midpoint
Continuous	Cont	W_i and W_j can be qualified; dimension is gradable
Discrete	Dis	W_i and W_j cannot be qualified; dimension is not gradable
Dichotomous	Dich	If W_i then not W_j; W_i and W_j are mutually exclusive
Spatial	Spa	W_i is spatially opposite W_j
Vector	Vec	W_i is directionally opposite W_j
III. Elements of agreement		
Inclusion	Inc	W_i is included in W_j semantically or physically
Overlap	Over	Meanings of W_i and W_j overlap; W_i and W_j are semantically similar
Intersection	Int	W_i is semantically included in W_j
Unilateral inclusion	Unil	W_j includes all of W_i but W_i does not include W_j
Bilateral inclusion	Bil	W_i include each other; W_i=W_j
Attribute	Att	W_j is an attribute of W_i; W_i "is" W_j
IV. Propositional elements		
Event	Evt	W_i and W_j related by an event
Action	Act	W_i and W_j related by an action
Agent	Agt	W_i is the agent of an action
Object	Obj	W_j is the object of an action
Instrument	Inst	W_j is the instrument used for an action
V. Elements of part-whole inclusion		
Partative inclusion	Partive	W_j is physically included in W_i
Locative inclusion	Loc	W_j is "in" W_i
Attachment	Attach	W_j is attached to W_i
Social	Soc	W_j is part of W_i by agreement
Homogeneous	Homog	W_j's are interchangeable
Component	Comp	W_j is a "component" of W_i
Property		W_j is a property of W_i
Possession	Poss	W_i "possesses" a property or attribute

Table 3. The relation elements used in Chaffin & Herrman (1986), with the abbreviations used in table 2, and definitions.

In table 2, each of the Relation Element Theory relations is shown, together with examples, and the set of 'relation elements' that make up that relation. These relation elements are shown in table 3, above.

The way in which these work can be illustrated by an example. The two relations "Contrary" and "Contradictory" are shown in table 2. It can be seen that they are similar in that for both relations they describe things that exist on a single dimension, and that in each case the things they describe are equidistant from the midpoint of that dimension, and on opposite sides of the midpoint. They differ because the dimension in the case of "Contrary" is continuous, whereas in the case of "Contradictory", things can only occupy discrete positions on the dimension.

According to Herrman and Chaffin (1986) comprehension of a relation between two words involve determining whether the words possess the elements that make up that relation. Some of the findings are reviewed below.

They review several investigations that show support for this theory. All these studies ask subjects to verify whether for a particular pair of words there is a relationship of a certain kind between the words (e.g. Given A: Robin, B: Bird, and the sentence: "A is included in the class of B", subjects would determine whether the sentence was true or false, and this would be used to test their comprehension of the relationship.).

In (Chaffin and Herrmann, 1984), subjects were asked for a typicality rating for the given word-pair of the relationship. This typicality was found to increase with the number of elements of the relation possessed by the word-pair.

Latencies of "no" responses, when correctly rejecting an unrelated word-pair as not being related in the way shown increased with the number of elements the word-pair had in common with the relation. Conversely, latencies of "yes" responses, where a word-pair was correctly identified as having a relation, decreased with the number of elements in common with the relation.

Chaffin and Herrman (1984) demonstrated that subjects were able to classify relations in a consistent manner, and in accordance with a set of five *a priori* groups of relations. Subjects in this study were presented with 31 cards, each with five examples of a certain relation on it (e.g. The card for the relationship "Class inclusion: Functional" had "musical instrument-violin, kitchen utensil-spatula, carpenter's tool-hammer, furniture-chair, vehicle-car" on it). They were asked to sort the cards by similarity, into two or more piles. The results were summarised in a 31*31 similarity matrix, each cell containing the number of subjects who had placed those two relations in the same pile.

It should be noted however that the studies they cite only test whether people can distinguish between some word-pair showing some specified relationship or not; it does not show whether people can consistently specify relations for word-pairs and get them right, or that people can consistently recognise a relation in a word-pair.
It is not clear from where their choice of the 31 relations they used originates. This is important as there may be great differences between a set of relations assumed *a priori*, and a set derived for the purposes of a particular task. In addition, it is not necessarily the case that these relationships, tested here between word pairs, will be found between pieces of information of the size of hypertext nodes

5.3. Story Grammars

Story grammars are important to the topic of linking in hypertext because they provide a description of how text might be comprehended. From these come some predictions of readers' understanding of a text.
Mandler (1982), describes a story grammar as a formal rule system used to describe regularities in the structure of stories - a "particular type of rule system with many attractive features as a notational system and a history of productive use". In (Mandler and Johnson, 1977) she describes a story grammar as simple rewrite rules (e.g., Episode = Beginning + Development + Ending) enabling a story to be expressed as a hierarchical tree with causal and temporal links traversing the tree. There is no processing mechanism, or cognitive tractability claimed.
Then in (Mandler and Goodman, 1982) she describes empirical testing of Story Grammars. The experiments tested:

(i) Reading and recall times of sentences within and across constituent boundaries, and found that first sentences were slower to read and recall than others.

(ii) Follow-up tests to (i) showed that these results were to do with constituent structure, rather than other factors (e.g. semantic relatedness).

(iii) The sequencing rules of the grammar were tested by moving constituents away from their proper positions, and again reading and recall times were examined. Performance deteriorated where a constituent was missing or inserted in the wrong place.

This concurs with work done on examining how readers comprehend canonical texts. Kintsch and Yarborough (1982) for example found that texts with rhetorical cues and canonical ordering are better comprehended than texts without these, but with identical content. The explanation put forward is that these features support

macroprocesses in comprehension, as comprehension measured in a way such that these macroprocesses would not be used showed equal results for good and bad rhetorical forms (only local comprehension was tested here). They conclude, "...various cues in the good version of the texts triggered the appropriate rhetorical schemata in the subjects. The subjects then used these schemata to organise the texts and they were quite successful in doing so because the texts conformed well to their schemata.".

Similarly, canonical forms of text are examined in (Dillon, 1991), and experimental evidence is given for the existence of a readers' model of an academic journal article, which facilitates processing of that article when read, and allows a reader to know where a given paragraph 'goes' in the text. It is difficult to extend this work to more general applications however as it deals with a very rigid text type being read by readers highly skilled in that text type.

Story grammars and work on canonical text structures do not deal with interrelationships in text, and so do not directly offer a basis on which to build a linking structure. However, they provide results which suggest how an effective method of hypertext linking might treat a text. For example, it may aid readers' navigation of a hypertext if links between hypertext nodes can be designed to make the reader's navigation through the information seem to flow more smoothly, and appear more like a structured, canonical information space, rather than discrete, independent nodes.

5.4. Expectation

Ehrlich et al (1982) hypothesised that there is a hierarchy of concepts that provides a context in which the reading of a text takes place.

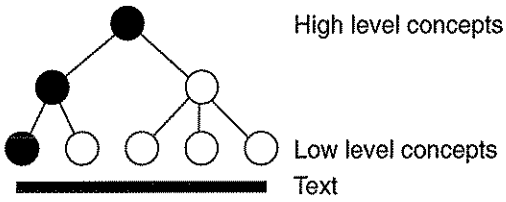


Figure 4. The text (bottom) is read left to right, and the circles above represent a taxonomy of concepts that occur in the text, with the filled-in circles being those concepts currently known to the reader.

He tested readers' knowledge of the content of various pieces of text throughout the reading process, and found that:

- "As soon as subjects became familiar with the first paragraph, all the directly superordinate paragraphs were activated." i.e. In the hierarchy of concepts illustrated in fig. 4 above, the text (at the bottom) is read from left to right and, the first part of the text having been read, the concepts 'above' it in the hierarchy have been activated.
- But, "access to the most abstract concept in the hierarchy did not allow subjects to anticipate the concepts corresponding to the text information of later paragraphs. Knowledge of a topic does not in itself allow anticipation of further events in the text".
- However, these higher-level concepts do work as retrieval cues for the text 'below' them.

To summarise; while, because of the vast number of ways a text can go from any point, knowledge of one paragraph does not allow anticipation of the next paragraph, it does give knowledge of the concepts overriding that paragraph which may facilitate retrieval of later paragraphs.

Whereas Ehrlich concentrated on concepts held in the text, Haberlandt (1982) looked more at features of the text that might facilitate expectation. He demonstrated that "comprehension, measured by sentence reading times, is facilitated when reader expectations match the evolving text". For example, comprehension, measured by a decrease in sentence reading times, is improved where there is a causal link, as in sentence 1 below, rather than in 2.

1. "(a) Brian punched George. (b) George called the doctor. (c) The doctor arrived".
2. "(a) Brian punched George. (b) George liked the doctor. (c) The doctor arrived".

More interesting for the subject of hypertext is where the cues that affect expectation are actual features of the text. In the example below, if the "However" in (e) is omitted the reader has no expectation of the rest of the sentence, and comprehension is found to be impaired.

> "(a) The jet had just taken off. (b) The left engine caught fire. (c) The passengers were terrified. (d) They thought the plane would crash. (e) However the pilot made a safe landing".

This last example demonstrates how expectation may be controlled by textual cues. It is the above features of expectation that the current work attempts to apply to hypertexts, using inter-text links as cues, such that provision of a piece of text and a link leading from it provides some expectation of what lies at the end of the link.

As it stands however, the work done on investigating expectation cannot be directly applied to hypertext systems. It does not give a full description of what text features will provide expectation in different situations or for different reading tasks. Moreover, whereas this work shows that expectation exists, using it as a tool in hypertext requires that, to be usable, it be made systematic and simple to understand.

5.5. Summary

The work discussed in this section shows the aspects of various linguistic models of text relationships that are of use when considering hypertext links. For reasons given in the discussion of each model, none of them were found to be appropriate to apply directly as relationships represented by hypertext links. However, what is useful about examining these models is what they show about how relationships act as part of the semantics of a text, as opposed to simply connecting two things.

6. EXAMPLES OF RELATIONAL LINKS IN HYPERTEXT

6.1. Links in Author's Argumentation Assistant (AAA)

AAA (Schuler, 1990) is a prototype authoring tool for creating argumentation-based hyperdocuments. AAA is discussed here:

1. As an example of a hypertext system with a set of meaningful, domain-dependent link types.
2. To demonstrate how a hypertext system can use and manipulate a small structure of nodes as a single entity.

Like gIBIS (Conklin and Begeman, 1988) AAA uses node types appropriate to the domain of argumentation; 'issues', 'positions', 'arguments', and 'facts'. Between these it uses link types which are specific to the domain of argumentation:

- serve (A,B): Issue B serves issue A
- replacement (A,B): Issue B is a replacement of issue A
- suggestion (X,A): Issue A is a suggestion from X, where X is an issue, position, argument or fact.
- answer (A,B): Position B is an answer to issue A
- objection (A,B): Argument B is an objection to position A
- support (A,B): Argument B is in support of position A
- contributes (A,B): B contributes to A
- reference (X,Y): Fact Y is a reference of X, where X is an issue, position, argument or fact.
- contradicts (A,B): A contradicts B

In addition there are operations for aggregating nodes, linking arguments to each other, to show support and objections between arguments, and for creating justifications for arguments by imposing Toulmin argument structures on the nodes used. Thus the Toulmin argument structure (Toulmin, 1958) is shown below in fig. 5.

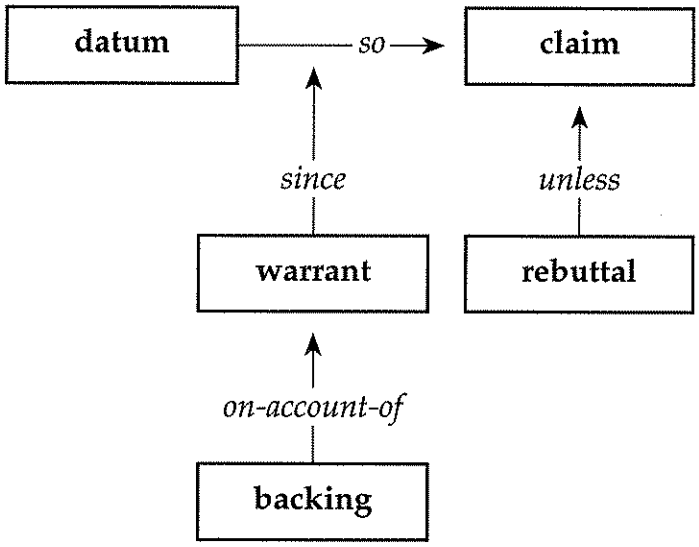


Figure 5. The Toulmin argumentation structure (Toulmin, 1958).

Thus in AAA, the 'claim' in figure 5 would be a 'position', the 'datum' an 'argument', and the 'so' link a 'supports' link. Then the whole Toulmin structure can be manipulated as one.

6.2. Textnet's taxonomy of link types

The set of links implemented in Textnet will now be considered. The first thing to note is that Trigg's (1983 and 1986) Textnet system and the link types that users could use within it were designed for a specific purpose, to support the ways in which people use academic literature. A requirement of the system was then that its users would be able not only to organise pieces of work, but also to comment on them. The set of link types then was divided into two, *normal* and *commentary* links (shown in table 4).

Normal links are to "connect nodes making up a scientific work, as well as to connect nodes lying in separate works". Commentary links are to "connect statements about a node to the node in question". Each link is between one chunk and another, and the size of the chunks is not fixed but could be a piece of text, a node, a whole work, or an entire topic area.

As well as the division between normal and commentary links, Trigg divided up the link types in Textnet based upon divisions he makes in the functions that a piece of

work (i.e. something that may include links) performs. These functions are now summarised.

The 'environment' is the context in which the work is placed. The (normal) *citation* links will show, for example, what pioneers in the field are referenced, and will identify work describing eponymous concepts, background work, and work not yet published or done. The (commentary) *environment* links will similarly connect the work with others, but commenting on the connection, for example *E-vacuum* suggests that the work should be related to other work in the field. The 'problem posing' function of a work includes the specification of problems which are then solved further on in the work, or are to be solved in the future. Links associated with this function include most of the normal links. 'Theory declaration' is where the 'thesis' of the work is described, 'Arguments' describes the route from premises to conclusions, and 'Data' describes any data presented as evidence or support for some other function.

Each of these functions will be more or less associated with a set of the normal links and a set of the commentary links. Trigg (1983) goes into the individual links' meaning in detail, but they are repeated here only for the purposes of illustrating the idea of a set of hypertext link types.

'Normal' links

Citation	Generalisation/ Specification	Summarisation/ Detail
C-Source	Abstraction/ Example	Alternate-view
C-Pioneer	Formalisation/ Application	Rewrite
C-Credit		
C-Leads	*Argument*	
C-Epon	*A*-Deduction	Simplification/ Complication
Background	*A*-Induction	Explanation
Future	*A*-Analogy	
Refutation	*A*-Intuition	Correction
Support		Update
	Solution	
Methodology		Continuation
Data		

'Commentary' links

Comment	*Points*	*Data*
Critical	*Pt*-Comment	*D*-Comment
Supportive	*Pt*-Trivial	*D*-Inadequate
	Pt-Unimportant	*D*-Dubious
Environment	*Pt*-Irrelevant	*D*-Ignored
E-Comment	*Pt*-Redherring	*D*-Irrelevant
E-Misrepresent	*Pt*-Contradict	*D*-Inapplicable
E-Vacuum	*Pt*-Dubious	*D*-Misrepresented
E-Ignored	*Pt*-Counter	
E-I-Supersede	*Pt*-Inelegant	*Style*
E-I-Refute	*Pt*-Simplistic	*S*-Comment
E-I-Support	*Pt*-Arbitrary	*S*-Boring
E-I-Repeat	*Pt*-Unmotivated	*S*-Unimaginative
		S-Incoherent
Problem Posing	*Arguments*	*S*-Arrogant
P-Comment	*A*-Comment	*S*-Rambling
P-Trivial	*A*-Invalid	*S*-Awkward
P-Unimportant	*A*-Insuff	
P-Impossible	*A*-Immaterial	
P-Ill-posed	*A*-Mislead	
P-Solved	*A*-Alternate	
P-Ambitious	*A*-Strawman	

Table 4. The link types used in Textnet, from Trigg (1983).

Both the names and meanings of the links and the functions of the texts that these links relate to demonstrate that the set of links is primarily applicable to the needs of

compiling, structuring and commenting on sets of academic works. The links are designed primarily for these needs, and may be inappropriate for other needs.

The set of links in Textnet was fixed, and therefore general-purpose but only over the domain of organising texts from scientific literature such that they can be used as a coherent whole. Also the aim of Trigg's work was not directed at establishing the 'right' set of link types, so the link types he used, while interesting, have no theoretical or empirical backing for their use as hypertext tools.

6.3. Dvorak's "reader centred" links

The work of Dvorak et al (1992), also being done at Queen Mary and Westfield College aims to arrive at the properties of links from an understanding of the reading strategies employed with paper books. She looks at how texts are structured to form a coherent discourse, and how text is put to use by readers in order to meet their reading goals. Then, from an understanding of how text is used will come a methodology to describe the linking structures that should be used in the text (these links she calls "reader centred" links). In addition her aim is that this methodology will make predictions as to how a paper-based text should be converted to a hypertext. However it does not directly address the idea of making the links usable across a range of information domains.

Fundamentally, Dvorak's work seeks to demonstrate that where a hypertext supports conventional reading strategies (through the use of appropriate link structures), a performance advantage is found over hypertexts that do not support these strategies.

The aim of Dvorak's work is that hypertext authors will be able to convert a book to a hypertext which will allow the users to continue to employ conventional reading strategies to meet their information goals. This will prevent the readers from being constrained by navigation tools which force the reader to employ strategies which are unfamiliar to them or which do not enable them to realise their reading goals as efficiently.

7. THE APPROACH DEVELOPED IN THIS THESIS

In the previous chapter hypertext was thoroughly examined. The conclusion reached at the end of the chapter was that hypertext was deficient in not allowing users to acquire a conceptual model of the structure of the information contained in the hypertext, and that this manifested itself in the cognitive overload and disorientation problems discussed there. Two means of remedying this can be seen. One is to provide a single structural model in some form, and this has already been done using such things as maps, browsers, indexes and guided tours. The other is to show the

user how the information is structured through the use of links. These two approaches are not necessarily in competition. It seems likely that the information that links may be able to give about the local structure of a hypertext system may not be able to be delivered through the use of a map, and similarly there may be information about the broad scope of the hypertext that could not be gleaned from looking at the links available from a single node. This issue, of how the different schemes for structuring hypertext overlap or complement each other will be looked at in chapter 6.

This chapter has examined ways in which links may be able to better show the structure of the hypertext system through emphasis of the relationship between the two nodes. Earlier in this chapter, the applicability of existing models of text organisation to the construction of domain-independent hypertext links was examined. However, because the tasks and behaviours which these models were designed to explain were too far removed from those of hypertext it was found to be inappropriate to directly apply any of them. Therefore, it was decided to approach the problem through empirical means.

The goal of the empirical investigations was to arrive at a set of link types that were independent of information domain and comprehensible to all hypertext users.

In doing these investigations, some notion of the nature of a relationship for the purposes of hypertext linking is necessary. This is because subjects will have to be tested to examine what relationships they can see and understand in a text, and will therefore have to know what kind of thing to look for. Secondly, when the links are added to a text for the purposes of testing their usefulness, the links' precise function will affect their placing in the text.

In this chapter something of the possible complexity of relationships for hypertext links is covered, and applications in hypertext for the different features of relationships are discussed. However, to simplify the experimental program and to make it possible to most directly test the principal hypothesis of this thesis, it was decided to make the relationships simple, with the idea that they could be extended at a later date. Therefore the relationships were to be simple, binary relationships with single names, and no constraints on the types of things they could link. Also no characteristics that implied manipulation on the relationships (e.g. transitivity, implication, consistency) were considered at this stage.

In the previous chapter and in section 3 of this chapter, many of the navigation and disorientation problems found in the use of hypertext systems were found to stem from the user (i) not knowing where to look next in the system, (ii) becoming frustrated with following links that did not go where the user expected them to go,

and (iii) having to cope with the 'cognitive overload' of having too many choices or paths to go down. The work done on expectation, described in section 5.4 of this chapter, by allowing some knowledge of what text follows a certain piece of text suggests an answer to these problems. If users looking at some text in a hypertext system can be given some knowledge of what text follows the links away from that text, they will be able to choose where to go next more effectively, and be able to ignore those links that obviously do not need to be followed.

Thus, because it had the most direct application to hypertext, expectation was taken as the starting point, and a relationship was defined as something that would, when taken in conjunction with a piece of text, facilitate expectation of another piece of text.

The initial goal of the experiments then was to see what domain-independent relationships subjects could see between pieces of information. Then when these relationships had been found they would be tested to see how usable they were in a hypertext setting.

8. CONCLUSION

This chapter explains the ways in which current linking methods in hypertext are failing the user. It also explains the need for relationships to be represented explicitly by links, and illustrates some of the attributes of relationships that can be used in doing this. Finally several theoretical approaches to text organisation, and their relevance to inter-text relationships are looked at and the approach to finding the set of relationships hypothesised in this thesis is established.

From this chapter comes the idea that a link in hypertext can be formal and well-defined in the manner of links with attributes like those of database links. There is also the notion from linguistics that links can be expressive and can play a part in the structure of a text's semantics.

What this thesis proposes is that hypertext links need to embrace both of these ideas. There is a necessity for formalism so that the links may be manipulated and so that links retain a common meaning wherever they occur. Also there is a necessity for links in hypertext to express something about the text they connect and to play a part in the text, in order that readers can use them to make inferences about what is around them in the hypertext.

4: Experiments 1

This chapter covers in detail the empirical derivation of a set of relationship types that could be used to add meaning to hypertext links. This work is based on investigating the relationships that could be seen in pieces of text by the users of those texts. There were two parts to this, the first a study identifying relationships that could be seen and expressed by the readers of texts, and the second study investigating whether other people could consistently recognise and classify those relationships.

1. EXPERIMENT 1.1 - STUDY OF THE RELATIONSHIPS SEEN IN TEXT

1.1. Purpose of the study

This study starts from the idea of a relationship in hypertext as something that, by showing the user how something else is related to what they already know, gives the user some expectancy of what that thing is. In a hypertext, such a relationship would be placed between two nodes or two pieces of text, and so the user, while reading one node, would gain some expectation of what information could be found at another node.

This study aimed to obtain data describing relationships that could be seen within a text by the users of that text. This was to be done by presenting subjects with two pieces of text, an explanation of what was meant by a 'relationship' in this context, and asking them what relationships they identified between the two pieces of text. This study was reported in (Bloomfield and Johnson, 1993).

The relationships, as was explained in the previous chapter, arose from the idea that usability problems in hypertext could be alleviated by making the structure of the hypertext more explicit. User disorientation would decrease as users knew more of what was around them, and users' cognitive overload would decrease as users became able to discriminate more accurately which links needed to be followed and which could be ignored. This lead to the choice of expectation as the mechanism that the relationship types would operate on and dictated the definition of a 'relationship' that was given to the subjects in this first study.

1.2. Choice of texts for hypertext

It was necessary to design the rest of this study to make it as relevant to hypertext links as possible and this influenced the choice of texts and the size of the text chunks that were given to the subjects. Hypertext allows new ways of structuring text, and when conventional paper-based texts are converted to hypertext, these texts are restructured to allow them to be used as hypertext. Dillon and McKnight (1990) suggest that some texts will be more suited than others to this conversion and that some texts will inherently be more useful to their readers if paper-based and some will be more useful as hypertext.

A way of distinguishing between texts which is informative in terms of how the texts are used and what readers might want from texts would be useful for distinguishing between those texts which would be usefully converted to hypertext and those which would not. Such a method might ideally show what reading tasks the text was to be used for and whether the text's structure lent itself to the restructuring that hypertext would impose on it. However, such a method has not been developed and little is known about either what reading tasks are optimally done in hypertext rather that text, or what texts are appropriate for conversion to hypertext. The choice of what text types to convert to hypertext mainly rests on very gross distinctions such as saying that poems or novels are generally not suited for conversion to hypertext[6].

Dillon and McKnight (1990) looked for ways to differentiate between texts in the hope of finding ways to describe texts which might then yield a distinction between texts that would be suited to conversion to hypertext and those which would not. They used a variety of different texts (including a conference proceedings, a journal, a textbook, a newspaper and a novel) and asked subjects for criteria to distinguish between the texts and then for how the texts scored on these criteria. They found that the texts could be broadly classified on three levels:

1. How they were read; e.g. serially or non-serially, once or repeatedly, browsed or studied in depth, etc.
2. Why they were read; e.g. for professional or personal reasons, to learn or not, out of interest or out of need, etc.
3. What type of information they contained; e.g. technical or non-technical, general or specific, etc.

[6]Yet hypertext might be a suitable way of reading annotations and commentary on poems or novels. This shows something of the difference between texts and the tasks for which they are used that would and would not be suited to hypertext.

However, this scheme cannot be used to differentiate between texts on anything but a broad level (such as the example they give, in which they show how a novel and a telephone directory answer these three criteria), and Dillon and McKnight do not attempt to integrate this scheme for describing text with what tasks are best supported by hypertext, an essential element if the aim is to produce some judgement on whether a text is suited to being presented as hypertext.

Neither the types of text used in hypertext systems or the tasks for which hypertext systems are optimally suited have been systematically described, and it may even be hard to arrive at anything but vague schemes for describing these. Therefore to choose the texts that will be used for this feasibility study it is necessary to base the choices on observation of text in other hypertext systems and to make some assumptions.

As might be expected from information-providing systems, the texts used in hypertext systems are typically reference works, providing explanatory and descriptive information. Examples of this type are the Charles Dickens hypertext system described by Phelan (1992), the system described by Mohageg (1992) giving demographic, economic, political and geographic information on North African countries, and that used by Carmel et al (1992) on the Vietnam War. Then others are more narrative, such as that of Marshall and Irish (1989) where the hypertext explains and guides the user through a complex legal case and Frisse's (1988) Hypertext Medical Handbook where the text is a mixture of procedural and reference information. Then there are hypertext systems which seek to educate and are designed for learning from, such as Egan et al's (1989) on data analysis and Zhao's (1994) on data structures in computing.

The texts range from those which have to engage the user (in the case of the Dickens hypertext, it was designed to be located in an exhibition) to those which can assume that the user is motivated enough by their desire to learn to maintain their attention. They also range from those which contain simple facts to those in which some narrative or procedural element is implied across the nodes. It would be difficult for an investigative study to arrive at a representative range of texts from which a set of relationship types should be derived, without (i) an examination of text types, (ii) a examination of what tasks hypertext supports and (iii) research into what text types these tasks require. For the purposes of the feasibility study it was felt adequate for the texts used in this experiment just to reflect some of this diversity of text types.

Obvious variants in the texts used in hypertext systems were the amount of narrative element in the texts, whether they describe a process or a thing, for example, and also the extent to which the text was purely a 'dry' reference work or tried to engage the reader. It was decided that these difference should be reflected in the texts chosen.

The texts chosen were a section from a travel guide and a section about clay preparation from a reference book on pottery. They are reproduced in appendices 1.1 and 1.2, and are described in the next section.

Again, with the choice of the size of the text chunks, there is some variation among hypertext systems, but with many the chunks are no larger than one or two paragraphs, being constrained by the screen or window size and the readability of on-screen text. In dividing the texts up for this study, the aim was to reflect a typical text chunk size. This is appropriate to the study's status as a feasibility study, where the aim is to examine the workability of the approach taken; for a more investigative study it might be appropriate, for example, to test a controlled range of sizes and to examine what dependence there might be between the relationship seen and the size of the text chunks it was seen between. Therefore the texts chosen were simply divided up into their separate paragraphs for this study.

1.3. Method

Subjects

Sixty subjects were used, mostly staff and students from within the Computer Science Department of Queen Mary and Westfield College (14 postgraduate Computer Science students, 3 undergraduate students, 19 members of the research and lecturing staff, 5 library staff, and 19 Administrative staff and others).

Design

The study was aimed at collecting data on what relationships could be identified between paragraphs in pieces of text. To enable variations in the types of relationships seen in different texts to be shown, it was planned to use two texts, and to counteract the variations anticipated in subjects' descriptions, it was thought necessary to use a large number of subjects.

Materials

The texts were (i) a passage from a travel guide (Cummings et al, 1986), describing a climb up a volcano, preparation needed for this, and relevant background material (12 paragraphs long) and (ii) a chapter about the preparation and storage of clay (Tyler, 1952), from a book on pottery (9 paragraphs long). These will be referred to as the 'Travel' text and the 'Pottery' text[7]. The texts were chosen to be different, reflecting the varied forms of text to which a domain-independent set of relationships might apply. The chief differences in the texts were:

[7]These texts are in appendices 1.1 and 1.2.

1. Different subject matter:
2. Different 'voice': The 'Pottery' text had a textbook style and described things in the passive voice, whereas the travel guide was more chatty, and used a predominantly active voice (e.g.: "You should not tackle this climb during the wet season...").
3. Procedural/ Declarative differences: The two texts differed here, the pottery text being mostly procedural and describing methods, and the travel guide being mostly declarative, without a strong flow of time through it.

The subjects were also given instructions, asking them to look at each of the paragraph pairs indicated, and if they identified a relationship between the paragraphs, to write it down. The definition of a relation given in the instruction was "This relationship should be such that if you were given the first paragraph and the relationship, you would be able to go some way towards anticipating the content of the second paragraph". The instructions are reproduced in full in appendix 2.

For each paragraph pair, the subject was asked to write down what relationship they saw between the paragraphs.

Other instructions the subjects were given were:

1. If you cannot see any relationship between the paragraphs, write this down.
2. If you can see a relationship, write this down, being precise about (i) what it is about the paragraphs that is related, and (ii) the nature of the relationship.
3. If the relationship can be expressed without using terms from the text, try to do this.
4. If the relationship works in one direction but not the other, indicate this.

These were to (1) stop subjects thinking that there had to be a relationship, and making guesses; (2) draw the subjects out on the precise nature of the relationship; (3) try to make the subjects abstract the relationship away from the subject matter; (4) test whether the relationships seen were directional.

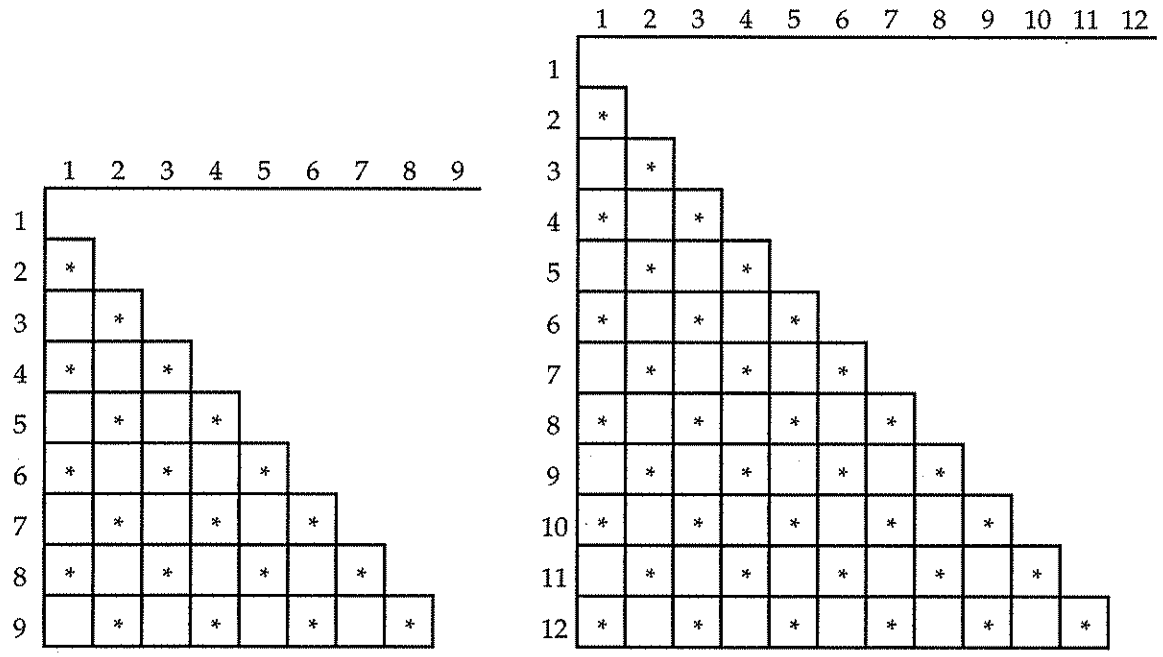
Finally, there was a questionnaire in which subjects were asked for their familiarity with the subject matter of each of the texts.

The experimental material was prepared in booklets so that subjects could take them away and complete them in their own time. To summarise, this comprised (i) an instruction sheet, (ii) a sheet with two lists, giving the paragraph numbers the subjects were asked to look for relationships between for the two texts, (iii) two sheets, each containing one of the texts, with the paragraphs numbered.

Procedure

Paragraph pairs were then chosen to be presented to the subjects:

- Pottery: Paragraphs numbered 1 to 9. There are therefore 36 unique paragraph pairs[8] to choose from in this text.
- Travel: Paragraphs numbered 1 to 12. There are therefore 66 unique paragraph pairs[9] to choose from in this text.



Pottery text Travel text

Table 5. The table shows the possible paragraph pairs for the Pottery text and the Travel text. The paragraph pairs marked with an asterisk are the ones that were used in the study.

Over the two texts then, there are 102 (36+66=102) paragraph pairs in all. Of these, 56 were used (20 from the Pottery text and 36 from the Travel text) distributed evenly over the paragraph pairs available, as shown in table 5.

The paragraph pairs used were split over 60 subjects, each subject being given 10 paragraph pairs to examine, 4 from the Pottery text and 6 from the Travel text. They were assigned to the subjects such that in each text, a subject would compare one

[8]The number of unique pairs it is possible to choose from 9 items: $\frac{9!}{(2!*(9-2)!)}=36$

[9]The number of unique pairs it is possible to choose from 12 items: $\frac{12!}{(2!*(12-2)!)}=66$

paragraph with all the others. For example, the paragraph pairs examined by one of the subjects were (8,1), (8,3), (8,5) and (8,7) in the Pottery text, and (6,1), (6,3), (6,5), (6,7), (6,9) and (6,11) in the Travel text. The paragraph pairs were assigned to the subjects like this in order to make the task less arduous than if a random set of ten paragraph pairs were assigned to each subject.

It was the intention to have each paragraph pair examined by at least 10 subjects, and this method of organising the study resulted in each paragraph pair used from the Pottery text being examined by 12 subjects, and each paragraph pair used from the Travel text being examined by 10 subjects.

Each paragraph pair was presented in both of its orientations; for example paragraphs 3 and 6 from one of the texts would have been presented as "3-6" to half the experimental subjects and "6-3" in the others.

Pilot Study

A pilot study was carried out with the aim of testing the experimental materials and seeing whether subjects would understand the notion of relationships as defined above. The materials differed slightly from those used in the main experiment; each of three subjects was given an instruction sheet, and five additional sheets, each sheet having two paragraphs from the "Travel" text. The difference in method is that the subjects were only given the paragraphs they were to look for relationships between, rather than the whole text.

The results of this pilot study showed that subjects were able to report many descriptive relationships between the paragraphs. However most of the relationships reported were either (i) similarities in the surface structure of the texts (e.g. both paragraphs contained the word "mountain"), or (ii) guesses, usually incorrect, of the paragraphs' relationship. Two of the subjects volunteered that the reason for this was lack of knowledge of the whole text, and so it was decided to give subjects the entire text, rather than isolated paragraphs in the subsequent experiment.

Subjects' knowledge of the entire text is not in conflict with the ultimate purpose of the relationships as links in a hypertext system where the user will not have knowledge of the whole text. This is because of the very different nature of the tasks of authoring and using these relationships. When using the relationships as links in a hypertext the user necessarily does not have knowledge of any of the text, yet the author needs some knowledge of the scope of the text, the range of subject matter, and the depth in which topics are explored in order to be able to determine how two things are related.

In summary, this study's aim is the generation of relationship types, which makes the subjects' knowledge of the whole text necessary. Therefore, in the eventual procedure for the study, subjects were given the whole text and asked to read it, but stress was placed on the necessity for the relationships they generated to be relevant to the paragraph pairs given to them.

1.4. Results

The subjects' level of response was good. Of the 60 booklets, 53 (88.33%) were returned, and of the 600 paragraph pairs divided among these 60 booklets, 514 (85.67%[10]) had been examined and had the relationship between them described. A complete list of these responses can be found in Appendix 3. Subjects reported their familiarity with the usage and format of travel guides to be better than with the Pottery text (On a 1 to 5 scale, an average of 3.2 as opposed to 1.6).

Responses for the directionality of the relationships were poor. This was the last of the things the subjects were asked to look for, and it is possible that a poor response rate for this part of the study was due to the large number of tasks the subjects already had had to perform.

In a small number of cases subjects had merely summarised the paragraphs without saying what it was that linked them. This could have been avoided by providing the subjects, in the experiment instructions, with examples of what they should do. This was not done though, to avoid influencing the subjects' responses.

'Response' is used here to mean the text written by a subject about the relationship between the two paragraphs of a paragraph pair. Differences in verbosity of the subjects were obvious, with subjects' responses varying in size from one word to 97 words, with an average of 14.2 words. Associated with this were differences in the amount of detail in the description of the relationships.

As a means of looking at the results, so that the prospects for further analysis of them could be judged, the subjects' responses were summarised, and put into rough categories of self-similar relationships. From this process, 19 categories emerged and they are shown below. Mostly, this involved no more than looking for synonyms; for example the category "EXPLAIN" - in 19 of the 33 members of this group the word 'explain' was used in the subject's response, and various phrases synonymous with this in the other 14 responses. It is important to note that the set of categories arrived at was not intended to be the most economical set, so there may be redundancies in

[10]The level of response was similar for the two texts - 85.55% for the travel text, and 85.83% for the pottery text.

the list and very little difference in meaning between some categories. Also it was not intended to be necessarily the most accurate division of the set of responses into categories, but rather point the way to future work. The choice of category names was made in order to distinguish and collate the distinct meanings in the subjects' responses, rather than to reflect the precise meanings of these categories.

This process was iterated - each of the subjects' original responses was reassessed and many were assigned to different categories, and minor changes were made to the set of category names.

An example of how this was done is shown below. Subjects A and B below describe how the same two paragraphs from the Travel text are related. These two responses were both eventually expressed as 'ADVICE'

A: 7 gives a practical warning about climbing the mountain. Practical advice.

B: Para 6 hints at why one would want to attempt an event, and para 7 gives advice on partaking in the event or journey.

An example from the Pottery text shows this again with another two subjects. In this case, subjects C and D's responses were expressed as 'EXPLAIN'

C: There is a strong relationship. They both talk about ways of obtaining the same material for use.

D: How to wash clay dug from the garden.

Below are reproduced all of the subjects' responses to one paragraph pair - paragraphs 6 and 7 of the Travel text. These responses show the range of responses made to a single paragraph pair, how some subjects saw different aspects of the relationships than others (e.g. compare G and I with L), and how some subjects went into greater depth than others (e.g. compare J with M).

E: Both paras seem to be talking about the same mountain

F: Gives a practical warning about climbing the mountain. Practical advice. (This was also one of the paragraph pairs of which this Subject said: "These relationships rather assume that the paragraph 6 motivates the reader to climb the mountain. Those readers with no wish to climb would probably say differently")

G: 6 describes the mountain, 7 warns of some of the difficulties of climbing it

H: Describes a mountain (volcano) which relates to climbing. It's height relates to the time it takes to climb (mentioned in 7)

I: 6 to 7 describes a route while 7 is a warning

J: Relationship - the mountain Rinjani (6,7)

K: Presumably 7 is speaking about the mountain in 6, but this is not specifically clear

L: 6 describes the mountain. 7 assumes you want to climb it. A relationship both ways - dependent on the other.

M: Para 6 hints as to why one would want to attempt an event, and para 7 gives advice on partaking in the event (or journey) Other than this vague relationship I see no other

N: Not possible to infer para 6 from 7 but 6 may provide further reasons for the statements of 7

The final set of categories arrived at is shown in table 6. In the 'Description', A and B denote two related paragraphs. The columns are:

n The total number of links of this type found.

n-> The number of cases where the paragraphs were presented in the same order as in the text (i.e. low numbered paragraph - high numbered paragraph).

n<- The number of cases where the paragraphs were presented in the reverse order from that of the text (i.e. high numbered paragraph - low numbered paragraph).

%Pt Percentage of relationships in the Pottery text of this relationship type.

%Tr Percentage of relationships in the Travel text of this relationship type.

Relationship type	n	n->	n<-	%Pt	%Tr	Description
COMPARE	3	1	2	0.0	0.8	Something in A is being compared with something in B
CONTRAST	4	2	2	0.0	1.1	Paragraphs A and B contrast something or are contradictory
ADVICE	43	25	18	3.6	9.0	B gives advice relevant to the information in A
DESCRIBE	13	5	8	2.5	1.6	B contains a description of something in A
EXPLAIN	33	10	23	9.0	2.2	B explains something in A
ELABORATE	20	11	9	3.2	3.0	B contains an elaboration of something in A
EXPAND	22	10	12	3.2	3.5	B contains an expansion of something in A
GEN->SPEC	33	18	15	5.7	4.6	A discusses some topic on a general level, while B deals with its specifics.
CONTINUE	46	23	23	11.1	4.1	Paragraph A continues on to B
PROC	41	17	24	13.6	0.8	There is a temporal link between A and B. There is a flow of time between A and B. B occurs 'later on' than A.
SUBJECT	147	61	86	18.6	25.8	A and B are on the same subject.
SUBJECT (DIFF. ASPECTS)	22	10	12	3.9	3.0	A and B are on the same subject, but deal with different aspects of it.
SUBJECT (GENERAL)	33	18	15	9.3	1.9	A and B are linked by a subject which is common to the whole text, not specifically to A and B.
SUBJECT (MINOR TOPICS)	11	5	6	0.4	2.7	A and B are linked by subject(s), not the main subject(s) of one or both of the paragraphs.
CONTENT	7	4	3	0.0	1.9	There were in addition a very few links that were domain specific. These were confined to the travel text and were to do with spatial relationships. For example, in the travel text one subject's response referred to the relationship between the position of two places, a village, and a place called 'Bayan' - "The village is high up on foothills - Bayan is 'beneath' it - lower down"
NONE	129	59	70	13.3	25.0	
NOT KNOWN	26	16	10	2.5	5.2	
SURFACE	13	6	7	0	3.5	

Table 6: Summary of responses from study.

In addition, and shown at the bottom of table 1, there were 129 responses in which the subjects reported that they could see no relationship at all between the two paragraphs. There were also 26 in which it could not be accurately determined what

the subject meant, and 13 where subjects had merely connected surface elements of the paragraphs.

The data in columns 2 and 3 ("n->" and "n<-") were collected to see if there was any bias in the number or type of relationships between the conditions where subjects were asked to look for relationships between low and high numbered paragraphs (that is, where the paragraphs are in the same order as in the text), and where they were asked to look for relationships between high and low numbered paragraphs (the reverse order to that in the text). This was done to see if there was any relationship strongly dependent on the order of the paragraphs in the original text. In fact, as the results show, this was not found to be the case, and there is no consistent, systematic difference between the data in the two columns. It should be noted, looking at this data, that only the order of the presentation of the paragraphs is referred to; they do not imply that the subjects reported the relationship as going in that direction.

The data in columns 4 and 5 ("%Pt" and "%Tr") above were collected to assess any differences in use of the relationships across information domains. Because the primary aim of this experiment was to see what relationship types could be seen rather than see how many were used in certain situations, this data can only be used as a guide. It does show though that most of the links were identified in both texts. Only those with a very low total response were not seen at all in one or other of the texts (COMPARE, CONTRAST, and CONTENT). The difference between the amount of narrative element in the texts, discussed in section 1.1 of this chapter is reflected in the number of 'PROC' relationships identified, with the Pottery text (which largely deals with explaining how various methods for preparing clay are carried out) containing many more of these than the Travel text. There are other interesting differences, the Travel text has more 'ADVICE' relationships for example, which also point to differences in the texts.

1.5. Discussion

One of the things that was apparent in the results was that the subjects' description of the relationships they saw seemed to show some dependence on their current task, or the goals they were currently seeking. A relationship type describes the function one piece of text has with respect to another As an example there might be a type "SUBJECT" which as a hypertext link would express the idea that the linked paragraph contains information about the subject of the currently viewed piece of text. But if this were a hypertext link, what it would actually be taken to mean would be

dependent on what the reader took the subject of the first piece of text to be, and this could be determined by their goals - the reasons for which they are reading the text.
For example, in the extracts below, the subjects O and P are discussing the same pair of paragraphs, and in both cases their responses were summarised as 'SUBJECT'. But whereas O saw the subject as the village called Senaro and the relationships between the villagers and tourists, P saw the two paragraphs as being linked by both being about villages in general:

O: [Paragraphs] 1 & 2 refer to the same village, Senaro ... Both refer to the relations between locals and westerners

P: They both talk about small villages

In this example, the topic which was considered to be common to both paragraphs was different for each of O and P. From this simple example, we can see how two hypertext users might follow a 'SUBJECT' relationship from a node with different expectations of what lies at the end of the relationship.
However, because the categorisation process used made no claims about great accuracy, the variability of relationship types seen in the same paragraph pairs cannot be properly analysed at present. Furthermore, analysis of the effect seen in the example above, where the relationship type is the same, but the information to which it refers is different would require knowledge of precisely what each subject meant when writing down the relationships they saw. In the cases where the subjects wrote down for example a one word response, such as "Explains", it is impossible to get this from the data gained in this experiment. Experiments designed specially to look at the effect of readers' goals on how they interpret relationships meaning would be needed.
A hypertext that truly reflected the information seeker's needs might have to be a sort of 'intelligent' explanation system. Either every possible purpose a reader may have for wishing to access a piece of information would have to be encoded in a link, or there would have to be some method of encoding of the information users' purpose as they used the system, and a customisation of the hypertext's structure as the system was used. These are both issues in the design of hypertext systems, and may be summarised thus:

- This may be expressed by a question: "How densely linked should a hypertext system be?". The issue is that there could probably be found a reason for wanting to link any given node in a hypertext system to any other given node. So when authoring links in a hypertext, taking account of every possible purpose for using the text would result in every node being linked to every other. This would burden the user, who may be using the hypertext

for only a single reason, with such a distraction of useless links as to make the hypertext system unusable. On the other hand, it would be possible to have too few links, making the user's goal in the hypertext system hard to reach, and so any specific hypertext system will necessarily be a compromise between these two extremes.

- The second issue concerns how much of a model of the user the hypertext system should build up, and how much it should attempt some sort of 'understanding' of the user's goals.

Both of these issues would merit further attention, but as they are not central to the aim of this thesis, they will not be investigated in depth here.

Summary

As stated above, the list of relationship categories in table 6, having only been the result of a cursory categorisation of the experimental results is not in its most concise or accurate form, and there are redundancies and overlaps in the list and very close similarities between some relationship types in the list. The important result from this experiment is the collection of subjects' responses, which will be analysed in the next section.

This experiment does however give some indication of the range of relationships seen by subjects. It also demonstrates that subjects are capable of explicating the relationships they see between pieces of text.

2. EXPERIMENT 1.2 - CLASSIFICATION OF THE RELATIONSHIP DESCRIPTIONS

2.1. Introduction

This experiment follows on from the previous study, and uses its results to arrive at a set of hypertext link types.

2.2. Purpose of the experiment

Experiment 1.1 resulted in a large collection of responses (514) from subjects to the request to describe what relationship they saw between two paragraphs from a text. These responses varied considerably in content and length. Therefore, to enable them to be of use to hypertext development, it was necessary to condense them into a set of relationships which contained the essential nature of the subjects' reported relationships.

Therefore, the purpose of this experiment was to extract from the responses a set of defined relationships, the meanings of which accurately reflected the relationships

reported in the first experiment, and which would be of use for hypertext development.

A secondary purpose was, having got this set of relationships, to be able to draw some conclusions about the similarities and differences between the relationships themselves; for example it would be interesting if a set of relationships was established that formed a hierarchy or some other structure as this might facilitate easier encoding of links, or manipulation of links by a hypertext system. To this end, what was wanted from the experiment was:

1. Information about what groups the responses from the study described in Experiment 1.1 fell into.
2. Information about similarities or interrelationships within the group.

As in the previous experiment, a relationship was defined as something that would cause a correct expectation of the semantic connection between two pieces of information.

2.3. Method

Design

Two experimental designs were considered. In the first, subjects are given the set of responses from the previous study as a set of cards (i.e. one response per card). They then sort this set of cards into as many piles of similar relationships as they like. From this, a matrix is drawn up showing how many times every relationship type was sorted into a pile with every other, and cluster analysis is performed to determine the relationships types. An advantage of this method is that it is easy for subjects to refer back to their previous similarity judgements during the experiment, allowing their judgement to be consistent throughout the experiment.

In the second method, subjects are given a number of sheets of paper, each with a pair of relationship types on it, and are asked to rank the similarity of the relationship types in the pair on some scale of similarity. A disadvantage of this method is that at the end of the experiment subjects cannot necessarily refer back to the similarity judgements they made at the beginning. This means that, having decided A is similar to B and dissimilar to C, they may then decide that B is similar to C, a decision they might not make with access to all their earlier decisions. A possible solution to this is to ask subjects to rank similarity (as before), but this time to do it by filling in a few selected boxes on a table (with the relationship types listed along both axes). A method of expressing and comparing different levels of similarity would also need to be established.

This second method though would entail too much work for the subjects if they were given all the responses to compare against all others[11], and if each subject was given only a subset of the responses to examine, then each subject's different perception of the total range of responses may affect how similar they would see two responses from that set. For these reasons then it was decided to adopt the first of these methods.

Naming problems

There are significant problems in finding the right names for a set of relationship types, such that the names will be short enough to be usable given the constraints of computer displays, and yet contain sufficient information such that their meaning is clear and similar to all users.

In Furnas et al (1987), the 'vocabulary' problem is identified - that is, the difficulty of choosing the right name to call some component of a computer interface, such that the user knows the meaning of that component. The problem occurs in any situation where a user has to refer to something in a system designed by someone else. Typically the designer will choose word(s) to denote something, which may not be the same as the users' choices of words, and communication is impaired.

Furnas et al (1987) describe various experiments. Users chose their own favourite words, and it was found that "there is no one good access term for most objects"/ "there can exist no rules, guidelines or procedures for choosing a good name, in the sense of "accessible to the unfamiliar user".".

Aliasing is recommended, and Furnas shows that near-100% success rates can be attained by increasing the number of aliases of an object. The problem then arises of imprecision - most system operations are too consequential to be guessed at by the computer where the user has entered a term whose aliases could resolve into two or more operations.

Their conclusions are then that use of a single access term chosen by a single designer leads to poor access; an empirically optimised single term results in better access; and use of unlimited aliases derived empirically results in near-100% access.

It was decided that the present experiment would look for definitions and descriptions of the relationships, rather than single-word names for them. These descriptions could then be given names, or aliases, by the end users of a hypertext they might be used in.

Materials

Because the number of responses from the previous study was large, to lessen the load on the experimental subjects, the 34 erroneous responses, typically where subjects had

[11]This would entail 514*513 comparisons (263,682).

misunderstood the experimental instructions, and the 129 responses in which the subjects had reported there to be no relationship were removed. This left 361 to be used.

Each of these was printed on paper and the text of the response was preceded with an arbitrary number (used for data collection purposes), the name of the text that the relationship was concerned with, and the numbers of the paragraphs from that text that the relationship was between. An example is shown below in fig. 6.

> [5] TRAVEL: Paras 1 & 2: 1 introduces the village, and 2 makes a 'back reference' - "the village itself". The implication is that an introduction has been read.

Figure 6. Example card used in Expt. 1.2

Subjects

As in experiment 1.1, there was no special skill or attribute that was being looked for or which had to be excluded from the subject group. The subjects chosen were 2 computer science postgraduate students, 3 members of staff, and one research physicist.

Procedure

Subjects were given a set of instructions, the two texts, and the set of 361 responses from the first experiment (these were called *relationship descriptions* in the instructions).

Subject's task

The instructions given to the subjects were to sort the relationship descriptions into a number of categories of self-similar relationships, and to describe what those categories were. Subjects were instructed that the categories of relationships should be different from each other, but could overlap or include one another in meaning. 'Similar' was defined as meaning that the *relationships* that were described were interchangeable. It was stressed that subjects should not make similarity judgements on the basis of content or subject matter. Subjects were allowed to create as many categories as they wished, but were not asked to assign relationship descriptions to more than one category.

The instructions given to the subjects are shown in appendix 4.

Finally, the subjects were asked to describe their categories, giving a full description of the meaning and scope of each category (They were encouraged to be verbose here, and provide a few sentences on each).

In summary then, the experimental subjects were each given 361 responses taken from experiment 1.1, and sorted these into varying numbers of categories, which they then named.

A pilot study was undertaken to ascertain how long the experiment might take and to test the experimental materials. No problems were found with the pilot study. Including the pilot study, six subjects completed the experiment.

2.4. Results

Each of the six subject returned the slips of paper with the relationship descriptions on them. These had been sorted by the subjects into several sets, each of which had another piece of paper with it, on which the subject had described the category of relationships that that set of relationship descriptions represented.

For each subject's data, each subject was assigned a capital letter, and each of the categories they reported was assigned this letter followed by a number (e.g. A1, A2, A3... were groupings that came from the first subject; B1, B2... came from the second subject, and so on). The number of categories reported by each subject varied, the six subjects reporting 13, 8, 10, 12, 6, and 9 categories. Their category descriptions varied between 1 and 205 words, and the number of relationship descriptions assigned to each category varied between 1 and 145.

2.5. Statistical analysis

This analysis was done by collecting data on which of the relationship descriptions different subjects had put into each of their categories. Having recorded all the categories from each subject, the aim of this analysis was to determine which categories were similar. This would then show whether different subjects had grouped the relationship descriptions in the same way, and which categories' descriptions could be merged for the purpose of establishing a set of relationship definitions.

The categorisations were each converted into several binary categorisations. For example, subject A had used 13 different categories (A1...A13); 359 of the 361 relationship descriptions were allocated to one or other of these categories, and the remaining 2 were placed in a 'missing' category. For this subject there were thus 14 categories. These 14 different categories became 14 different binary variables and, for each of the 361 relationship descriptions one of these variables takes the value 1 and the others take the value 0.

This was done for each subject, and a matrix was produced combining all the categories produced by all the subjects, a total of 62 categories. The data matrix had 361 cases corresponding to the 361 relationship descriptions, and a total of 62 columns.

Each cell in the matrix contains a binary variable signifying whether a certain relationship description was put into a certain category. For any given relationship description, because each of the six subjects will have assigned it to one of their categories, across the 62 columns, there will be 6 cells with the value '1' in them.

A hierarchical agglomerative cluster analysis using average linkage between groups (Jardine and Sibson, 1977 and Lorr, 1983) was carried out using the Cluster routine within the SPSS package (SPSS, 1990).

Reported here are the results of the variables analysis, which corresponds to cluster analysis of the categorisations. The analysis was carried out using two different dissimilarity measures. Both were obtained by taking an appropriate similarity measure, then negating and rescaling to form the corresponding dissimilarity measure. The first similarity measure was K2 (Kuczynski's 2nd) and the second Jaccard's. K2 gives the average predictability of each of the categorisations by the other; Jaccard's measure gives the proportion of overlap of two categorisations. K2 was felt to be preferable because a category that is essentially included in another is grouped with it earlier in the clustering, rather than being left hanging until near the end of the process.

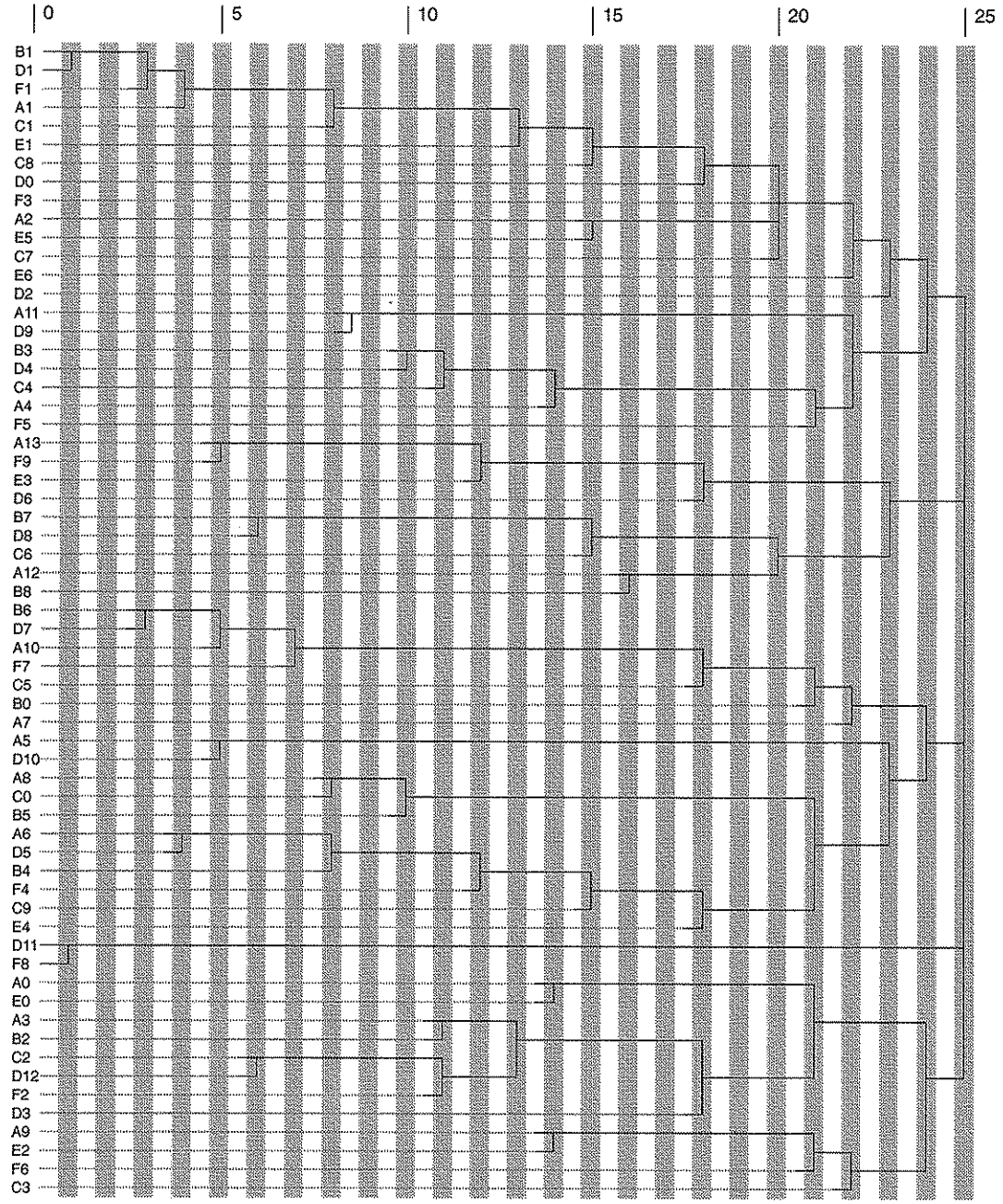


Figure 7. Representation of the K2 cluster analysis.

In fig. 7, capital letters signify experimental subjects, and the numbers signify the categories which that subject created. The apparent correlation between these numbers and the clusters (e.g. the first categories from each subject are all clustered together at the top of the diagram: B1, D1, F1, A1, C1, E1) arises from the largest pile of responses from each subject (i.e. the category they put most relationship descriptions into) being assigned the number "1".

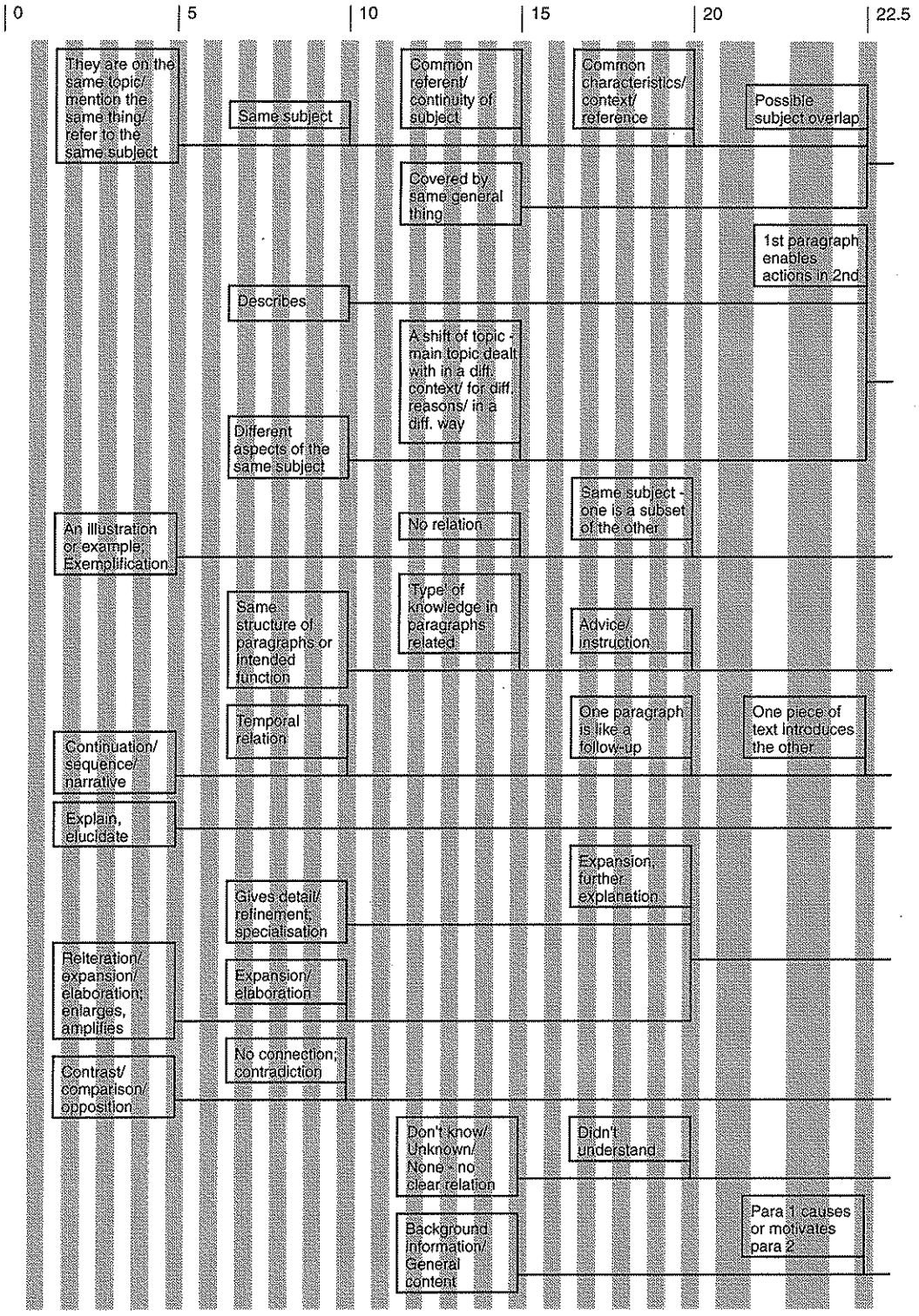


Figure 8. Representation of the K2 cluster analysis, showing excerpts from the category descriptions.

The numbers on the horizontal axis show a rescaling of the similarity measure, and signify how similar two categories or clusters have to be for the algorithm to cluster

them together. The numbers that represent this similarity measure are not significant. The left hand side of the diagram represents the case where for two things to be judged similar they have to be identical, and the right hand side of the diagram represents the case where anything will be judged to be similar to anything else.
Thus, on the extreme left of the diagram all the categories are separate, and on the extreme right they are all grouped together into one cluster. Therefore if single categories are ignored until they are included in a cluster with something else, progressing from left to right, the number of clusters there are at any point will vary.
For example, at the bottom of the chart, the category C3 is ignored until it is grouped at about the value 21 on the horizontal scale. Also, it can be seen that at the value 15, there are 14 distinct clusters. The textual descriptions of each of these categories (i.e. A1, A2, A3 ... A13, B1, B2, B3 ... B8, C1, C2, C3 ...F9) can be found in Appendix 5.
The clusters A0, B0... F0 denote the relationships which the subjects failed to categorise. The distribution of these is not significant, and they are ignored in the final cluster analysis (fig. 8).
Fig. 8 shows the clusters arranged in the same way as they were in fig. 7. In this diagram though, excerpts from the subjects' descriptions of their categories have been added, and the horizontal scale has been simplified (effectively, fig. 7 has been sampled at the values 5, 10, 15, 20, and 22.5 on the horizontal axis. The scale on fig. 8 does not go up to 25, as that in fig. 7, because all the categories become one cluster there.). As might be expected, in fig. 8 the categories that are included 'later on' in the cluster analysis, or further to the right of the diagram, because they have to be less similar to be included, tend to be removed in meaning from those included 'earlier', towards the left of the diagram. So each branch of the cluster analysis as a whole, progressing towards the right of fig. 8 goes from being specific and particular to being general and more inclusive in meaning.

2.6. Implications and discussion

The results above show that there is consistency between the types of relationships seen by different people. This makes it possible to derive a generalised set of definitions of relationships from these observations. In respect of the thesis being put forward here, the experiments described support the notion of there being relationship types that are commonly applicable to the two information domains from which the relationships originated. They also support the idea that these relationships types can be accurately recognised by a range of people.

It is important to note that the set of relationship categories arrived at cannot yet be said to be a 'complete' set. They derive from observations of relationships in only two information domains and in two similar text types, and further experiments on more information domains and text types would have to be done before applying them on a large scale.

In order that this work may be applied to hypertext systems, the set of relationship definitions represented in fig. 8 needs now to be turned into a navigational tool. There are two ways in which a set of relationships could be derived from these data. The first would be to draw a vertical line on fig. 8 at some similarity value, and use each of the clusters that intersected with that line as a relationship (so, only those categories that are clustered to the left of the line would be included). This would be the simplest approach. The other approach would be to use the hierarchy created by the cluster analysis as a set of relationships itself (This hierarchy can be seen most clearly in fig. 7). A link type could be chosen from any of the clusters, as before, but also at any point on the horizontal scale, thus allowing its precision or inclusiveness to be varied. The first of these two ways would be easier to implement, and would avoid the extreme left and right sides of the diagram, where the relationships may be either too specific to be of any use, or too general to provide any information. On the other hand, the second method would retain information lost by the first method about the different levels of generality a relationship could have. A study of the precise merits of these two methods is a topic for further work. Immediately however, in the application of these links to a hypertext system to test aspects of their usability, the first, simpler method will be used. This is chosen because, since the classification was done by a relatively small number of subjects, some parts of the hierarchy of clusters are based on a small data sample, and may change when the categorisation is done by more subjects. In addition, and for the same reason, there is not enough granularity in parts of the hierarchy to properly reflect any continuum there may be from one side of the hierarchy to the other.

"Naming problems" were discussed in section 2.3, that is, the difficulties in choosing a name for something such that it has a similar meaning for a large group of users. Because of this the *descriptions* of the relationships derived from the category names chosen in this experiment (and summarised in fig. 8) will be used in the experiments, rather than single word descriptions of them. These descriptions may then be given names, or aliases, by the end users of the hypertext.

Using this method on the clusters shown in fig. 8, drawing a vertical line at the value 15 in the horizontal axis, gives us 13 clusters. Using the descriptions of the categories

clustered to the left of the line, and ignoring the cluster of categories described with terms like "Don't know" and "Didn't understand" gives us the following 12 groups:

Relationship 1

- The two pieces of text refer to the same thing, they are on the same topic, they mention the same thing
- Both paragraphs refer to the same general subject
- We know that some common context should be there and reference is made to that, but we do not know the subject or content about one or both of the paragraphs. Same subject, but not specific to these two paragraphs. *[Reference is made to common subject matter, a general subject matter]*
- Common reference, but nothing else. The relationship refers to the content, not the subject. There is no other relationship mentioned but a common bit of content, common reference in the content. There is a common element. *[A thing common to both paras is reported - this isn't necessarily the main topic of either paragraph]*
- Same subject (General). Includes very general "weak" and "strong" relationships - could be separated into two.
- Continuity of subject
- "Complements" - the two paragraphs present observations upon the one topic (a generic relation!) without being specific enough to categorise as elaboration, etc.

Relationship 2

- The two paragraphs talk about different things, but which are covered by the same general thing
- Specific content - strong subject overlap

Relationship 3

- One paragraph describes something from the other or something relevant to the other.
- Describe - one describes the other, or describes something in the other

Relationship 4

- There is a small shift of topic - The main topic remains the same, but is dealt with in a different context/ for different reasons/ in a different way
- Paragraphs discuss different aspects of the same subject

- They are related by subject/content. The relationship is identified by describing some aspect of the content in each of the paragraphs related. The relationship refers to commonality of theme, different aspects of it. *[common subject/ theme reported in both paras, but dealt with in different ways in each paragraph]*
- Same subject (different aspects) i.e. disjoint, although in the context of the overall text, otherwise no relationship.

Relationship 5

- An illustration or example/ analogy of something in one piece of text is given in the other
- Exemplify: One paragraph provides an example to illustrate a concept introduced by another

Relationship 6

- The structure of paragraphs and intended function is the same (regardless of context or the content of the paragraphs)
- The kind of the relationship is identified without reference to the subject/content at all. The relationship talks about the 'type' of knowledge/ information that is found in the text without reference to its content *[Some relationship identified without the paragraphs' subject matter being identified]*
- Same function. e.g. both give advice, facts, both describe/ explain, although don't have to be same subject.

Relationship 7

- Continue - There is a sequence of steps in some process or narrative which carries over from one piece of text to the other; a natural progression, maybe a flow of time as well.
- Continuation - One paragraph naturally follows the other
- Same subject; directional, progression. Continuation, can be temporal.
- Sequential - The paragraphs described are related temporally, one precedes or succeeds the other

Relationship 8

- One piece of text explains something in the other, answers "Why?" questions, describes the reasons for something aid in the other piece of text.
- Explain, elucidate - why, how, one explains the other

Relationship 9

- One piece of text gives detail on something from the other. There is a refinement, or one piece of text may be much more specific than the other.
- Specialisation - One paragraph is introductory on a subject, the second specialises

Relationship 10

- One piece of text reiterates what is in the other, but more fully. There is an expansion or elaboration
- Expansion/ Elaboration - One paragraph explains a concept mentioned in the other (It may not be the same subject of the other paragraph)
- A description of the type of relationship is offered along with some information on the content. They are related by type, but also by some connection of the theme. *[The type of relationship and the subject matter are reported]*
- Expand, elaborate, enlarge, amplify
- Elaborates - One paragraph provides expansion of a point raised in the other, providing the detail necessary to make a point or explain a concept. 'Generalises' can be regarded as the opposite relation.

Relationship 11

- Contrast, compare - one contrasts, compares with the other
- Contrast: The paragraphs present contradicting statements, or present opposed views

Relationship 12

- One piece of text gives background information relevant to the other.
- General content - weak subject overlap

The differing number of descriptions in each relationship arises from two effects. Some relationships include a lot of descriptions because more than one category from individual subjects were put in the same cluster. That is, where one relationship is shown above, these subjects may have seen two or three. Some relationships contain only a few descriptions because a particular relationship was recognised only by those few subjects who created a category fitting that description.

It should be borne in mind that there was no guarantee that different descriptions in the same cluster would be similar in meaning. These 12 relationships arise out of similarities in the subjects' groupings of the responses from Experiment 1.1 and their subsequent naming of those groupings. Suppose, as an example, subjects A and B had

created groups of responses from Experiment 1.1. Then the cluster analysis deemed that two of the groups (one from A, one from B) were similar enough to be clustered together. These two groups, a_1 and b_1, each have descriptions given to them by A and B respectively. These two descriptions, $a_{1\text{-}description}$ and $b_{1\text{-}description}$, will both be included in one of the 'relationships' shown above.

The implication of this is that similarities seen between the descriptions that make up each relationship are present because subjects firstly sorted responses from Experiment 1.1 into similar groupings, and secondly, gave those groupings similar descriptions. On inspection of the descriptions that make up individual relationships, there can be seen to be similarities between many of them. This suggests that there is some consistency in the sets of relationships seen by different subjects in this experiment. It would be sensible to do some work to test the consistency of meaning between different descriptions in the same relationship, however, this would be more useful after future work is done to base the relationships on a wider range of text types.

Looking at the set of relationships it will be seen that there are some overlaps between the relationships, mainly between types 1, 2, 4, and 12. These overlapping relationships still have individual meanings, but in each case some aspect of their meanings appears to overlap with that of one or more of the others. There are two possible causes of this. The overlaps could arise from the categorisation process and may be prevented if this was done by more subjects or if a way was found to define the subjects' categories more accurately. Alternatively taking the relationship types from the cluster analysis in a different way, as was described above (i.e. by using the whole hierarchy, or by sampling the cluster analysis at a different similarity value) would result in different category descriptions being assigned to each of the relationships which would then change these relationships' meaning. The issue of similarities and differences between the relationships is one that needs to be addressed. Since each of the relationship types appears to have a distinct meaning with only small overlaps in meaning between them, and there are no contradictions in meaning between the category descriptions that make up each relationship type, they will be used as they are and the issues raised above will be returned to later.

The next step in this research is to test their usefulness. These groups will be used in the experiments in the next chapter as descriptions of the relationship types in a hypertext system.

3. CONCLUSION

The previous chapter focused on what was meant, for the purposes of this thesis, by a relationship, and on the idea of a set of hypertext link types embodying such relationships. This chapter covers two experiments designed to arrive at these relationships.

The first experiment (Experiment 1.1) was a study designed to show what relationships, of a kind appropriate to hypertext, could be seen in a text. The second (Experiment 1.2) was designed to produce an abstraction of the responses from Experiment 1.1. The combination of these two studies is the set of relationships seen above.

The next step is to test the relationships. As was mentioned above, a test of how consistently different descriptions were allocated to the relationships would provide insights into how consistent different subjects' views of the set of relationships was, and how consistently they attributed similar meanings to similar categories.

More important though is the test of these relationships as links in a hypertext system. From chapter 2 came the idea that one cannot address problems with components of hypertext in isolation of the effect on other components of hypertext. It was argued that this was the case because of the complexity of the user's interaction with a hypertext system, and the same is true of developing hypertext components; it would be meaningless to test them and draw conclusions from this, without building them into a hypertext system and making the testing environment as realistic as possible.

5: Experiments 2

Relationship types were developed in the previous chapter, with the aim that they should form a set such as was hypothesised in the initial chapters of this thesis. The previous chapter showed that it was possible to develop a domain-independent set of relationship types. This chapter will describe the experimental work that was carried out to test these relationship types' usage in a hypertext system. It was necessary to do this because of the combination of usability problems, tasks, and interface characteristics that is particular to hypertext systems, and which were dealt with in chapter 2. Their presence makes it unreasonable to infer that the relationship types found in the previous chapter could be successfully used as links in hypertext without implementing them as hypertext links and performing appropriate tests.

The evaluation consists of two experiments. Experiment 2.1 tests aspects of the links' usability in a realistic hypertext environment. Experiment 2.2 tests the aspect of the link types that, it was hypothesised would afford users some expectation of what a link led to.

1. EXPERIMENT 2.1

1.1. Purpose of the experiment

The analysis of the problems associated with hypertext links, summarised at the end of chapter 3 suggested that the commonly seen problems of disorientation and cognitive overload are caused in part by the user not being given or not being able to infer a clear model of the hypertext system. Ways in which the linking structures in hypertext systems could remedy this were examined, and the mechanism of expectation was decided on. This would allow users some knowledge of what nodes were immediately accessible to them by showing how information in those nodes related to the information on the 'current' node. Thus, disorientation would be lessened because users would know what information lay around them, and cognitive overload would be lessened because users would be able to, with greater knowledge of where the links go, discard some of them as being uninteresting.

It would be extremely difficult to directly test or to quantify the degree of 'disorientation' or 'cognitive overload' experienced by users of a hypertext system.

Most importantly, it would be difficult to show whether the results of any such experiment were applicable to actual use of hypertext systems. This is because of the large degree of uncertainty about what affects hypertext usage and the large number of variables that could affect users' performance in a hypertext. Therefore it was felt to be both safer in terms of what could be concluded, and also more practical for the purposes of the feasibility study to test whether users' performance in the hypertext improved, rather than to concentrate on what the mechanism was that caused that improvement. The experiment was therefore aimed at testing whether use of the relationships as links in a hypertext was associated with improvements in users' performance.

1.2. Method

Design

Experimental hypotheses

The chief experimental hypothesis was that the relationship types described in the previous chapter would provide a usability advantage when added to the links in a hypertext. What constitutes 'usability' in hypertext is hard to define because of the different priorities users of hypertext may have. For example one user may want to look briefly at an overview of some subject, whereas another user may require that a subject be covered in as much depth as possible. So, the factors that characterise someone's usage of a hypertext system, such as time taken, number of links traversed, and amount read will vary from person to person, depending on their needs.

The following factors will certainly contribute to making a hypertext system easy to use, although as has been suggested, individually they may be more or less important to different users.

1. Reduction in the time needed to gain access to the information being sought.
2. Increase in the amount of information on the subject being sought presented to the user.
3. Reduction in the number of link traversals made by the user to reach the information sought.

The hypothesis of this experiment is that relational links in a hypertext will provide some usability advantage. What is meant by this is that usage of a hypertext system can be made more efficient, implying that users of a hypertext system perform tasks with less effort, or achieve results of improved quality. A combination of the 3 factors above could comprise some notion of efficient usage of a hypertext system, although there may be trade-offs between them (For example 1 and 2).

Expressing this in terms of aspects of the subjects' behaviour that could be measured, the following set of hypotheses was proposed:

(a) Subjects would preferentially use the relational links.

(b) Subjects would answer the questions more accurately.

(c) Subjects would answer the questions faster.

To test (b), a comprehension task was planned, which is discussed below. To test (a) and (c), it was planned to investigate factors relating to subjects' usage of the hypertext system. These were:

- The time taken to answer each question
- The numbers of relational and navigational links traversed. By 'relational' links is meant the links which use the relationship types derived in the previous chapter. 'Navigational' links include links such as allow the user to move linearly through the text, to go straight to either end of the text, or to navigate a hierarchical representation of the text based on the text's division into sections and subsections.
- The ratio of navigational to relational links used. This ratio could show where subjects used relational links in preference to navigational links, or vice versa.

Data were also collected on factors that could have affected the results, such as subjects' knowledge of the domain of information of the hypertext and previous usage of hypertext systems.

The experiment

The task the experimental subjects were assigned was to use a hypertext system to find the answers to a set of questions. Having found the correct information in the hypertext system they were to answer these questions and write a short answer to each question.

Before the experiment, subjects were tested for knowledge of the subject domain. This was done by asking them to answer the set of questions before their use of the hypertext system. Then, their success at answering the questions both before and after using the hypertext, as well as their usage of the hypertext system could be measured.

Alternative methods were considered; for example, a possible method of testing the effectiveness of the relational links might have been to be to allow all subjects to achieve the same results in their work using the hypertext system and then to examine differences in their behaviour. However to have done this would have risked making the exercise so artificial as to not reflect how subjects might use a real hypertext

system at all. Thus, the hypotheses given in the previous section are necessarily constrained by the need to test subjects' performance in a hypertext system while altering how they might use a hypertext system as little as possible.

This experiment was to examine hypertext users' behaviour in the cases where they did and did not have explicit information of the meanings of the relational link types. This was to be achieved by showing the links in the hypertext system either with or without a label describing the link type. In addition the experiment had to be designed so that any alterations in the subjects' usage of the hypertext system across these conditions could be attributed to the link types themselves, rather than any other difference between the conditions.

Therefore, as well as either showing the link type labels or not, another condition was introduced, either differentiating the link types by colour or displaying them all the same colour. By doing this it was possible to control separately whether the subjects knew that there was a variety of link types and whether they knew what those link types were. Showing the hypertext system's users the different colours but not the labels which showed the names of the link types would allow them to know that there were different link types with different meanings, but not what those meanings were.

There were therefore two conditions, each of two levels. These were (i) whether the link types' labels were displayed, and (ii) whether the link types were differentiated by colour. The experiment was a simple 2*2 design with subjects randomly assigned to one of four treatments. These treatments were:

1. *{control}* Subjects were shown all link types the same colour, with the link type labels not displayed (the 'control' treatment).
2. *{C}* Subjects were shown each link type assigned a different colour, with the link type labels not displayed.
3. *{LL}* Subjects were shown all link types the same colour, with the link type labels displayed.
4. *{C+LL}* Subjects were shown each link type assigned a different colour, with the link type labels displayed.

The numbers on the left in the above list and the labels in italics will be used to refer to these four treatments.

Subjects

Thirty-two subjects were used (20 postgraduate students, 3 undergraduate students, and 6 staff from the Computer Science Department of Queen Mary and Westfield College, and 3 from various commercial fields).

Materials

The experimental task

In chapter 4 some evidence was shown that subjects' perception of the relationship between two paragraphs depended on their goals and understanding of the text. Therefore it is necessary to ask for what purposes the text will be read, and control these purposes as much as possible by setting identical tasks for all the subjects.

The task was to answer questions about some aspect of the content of the hypertext system. Suitable questions could be derived in three ways:

1. Inspection of the text; if there are obvious, plausible questions, use these.
2. Use the purposes the text was written to be read for. These could be obtained by asking the text's author.
3. Ask experienced users of the text for questions that might be answered using the text.

The necessity to be able to find suitable questions to ask the experimental subjects formed one of the criteria used when looking for a text. The actual text used is described in the next section.

There were four questions set for the experimental subjects to answer; these are shown in the instructions given to the subjects, reproduced in Appendix 6. The questions differ not only in complexity, but also in how their answers could be found in the hypertext system. These differences are found in the distributions of the questions' answers across the hypertext system and the routes it was necessary to take to get through the hypertext system to get to the answers.

The distribution of the answers varied in the number of nodes it was necessary to visit to get the complete answer to the question. The answers for questions 1 and 3 were each spread over 3 nodes, the answer for question 4 was spread over 5 nodes, and the answer for question 2 was on a single node. Subjects had no definite way of knowing when they had accumulated enough information for a complete answer, and so it was thought this variability in the number of nodes over which the answers were spread could have provided some indication of the effectiveness of the relational links in pointing the way to related pieces of information in a hypertext. However, this is not a manipulation upon which it is possible to make strong hypotheses. This is firstly because knowledge of the locations where pieces of the answer for a given question could be found may have been affected by the experiences of answering a previous question. Secondly, as well as varying in the ways their answers were distributed

throughout the hypertext system, the questions themselves may have varied in ways which were not controlled for but which affected their difficulty.

The text

First, it was necessary to choose a text that would be converted into a hypertext for the purposes of the experiment. The criteria under which this text was chosen were that:

- It should have identifiable purposes for which it might be read. This was necessary in order that plausible tasks could be given to the experimental subjects
- It should be sufficiently complex so as to contain examples of all the link types.

The text chosen was (Johnson, 1992), a university textbook on Human-Computer Interaction. It was chosen because it met the above criteria and included questions at the ends of the chapters, which could be used to ask the experimental subjects. Also there was ready access to subjects both expert and novice in the content of the book. From this book, a single chapter (Chapter 2, "An introduction to Human Memory") was chosen to convert into a hypertext.

The hypertext system

The next step was to set up the hypertext system to be used in the experiments. This system needed:

- The capability to display the 12 link types so that they were easily distinguishable. They had to be able to be displayed in 12 easily distinguishable colours.
- The means to display the position of a link in the text (the 'anchor') and to optionally associate a colour and/ or a link type label with that anchor.
- The means to allow the user to follow a link.
- A simple display, showing one node at a time. It had to be simple because anything not directly concerned with testing the link types should be left at a basic level. Indeed it had to be left simple to avoid the possibility of other hypertext features interfering with the experiment. Thus, no map or browser was needed.
- Simple navigation links. These were "Back" to go to the node most recently visited, "Next" and "Prev" to go to the next and previous nodes in the linear organisation of the text, and "First" and "Last" to go to the first and last nodes in the linear organisation of the text. There was also a simple hierarchical organisation of the text, based on how the text was broken up

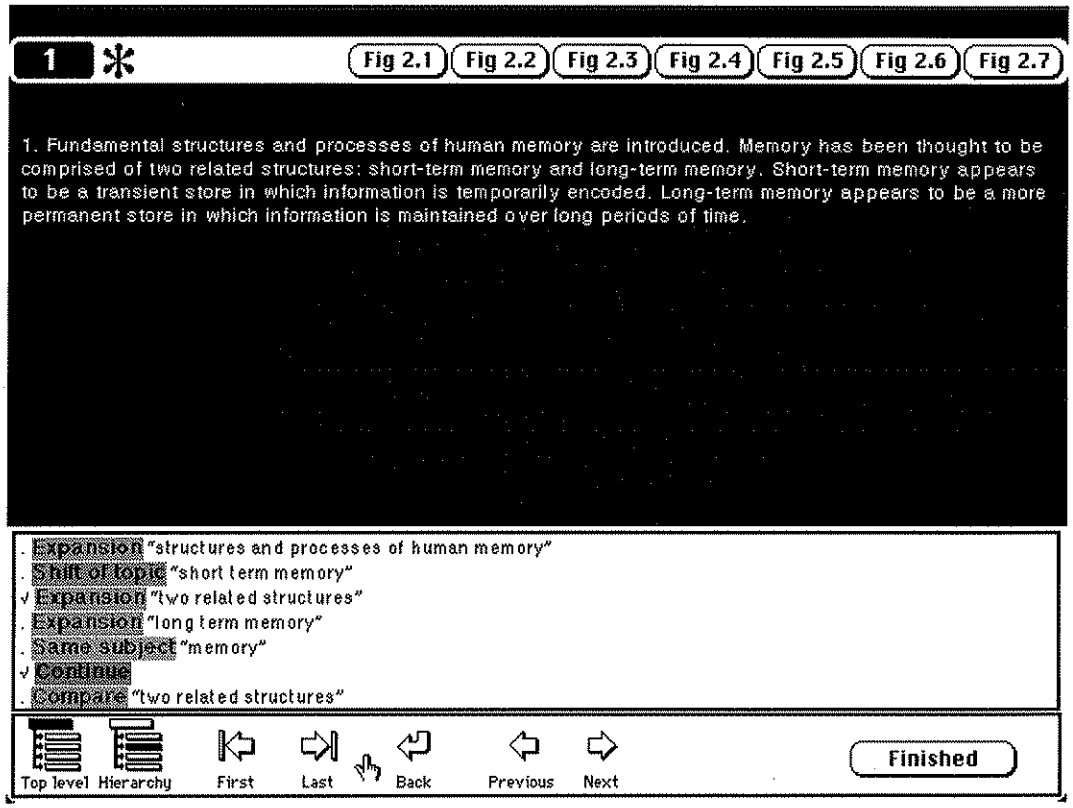


Figure 9: The first node in the hypertext. The links are shown as they would have appeared for subjects in treatment 4 (Although, of course they would have been in colour). If the subject were to follow the link "Expansion: Two related structures" they would be presented with the screen shown in fig. 11.

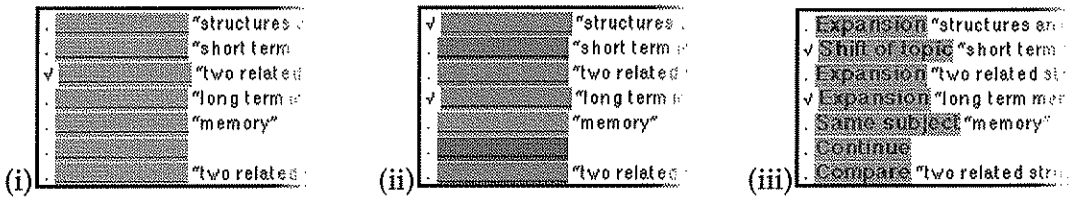


Figure 10: The links on the first node of the hypertext (as in fig. 9) as they would have appeared to subjects in (i) treatment 1, (ii) treatment 2, and (iii) treatment 3.

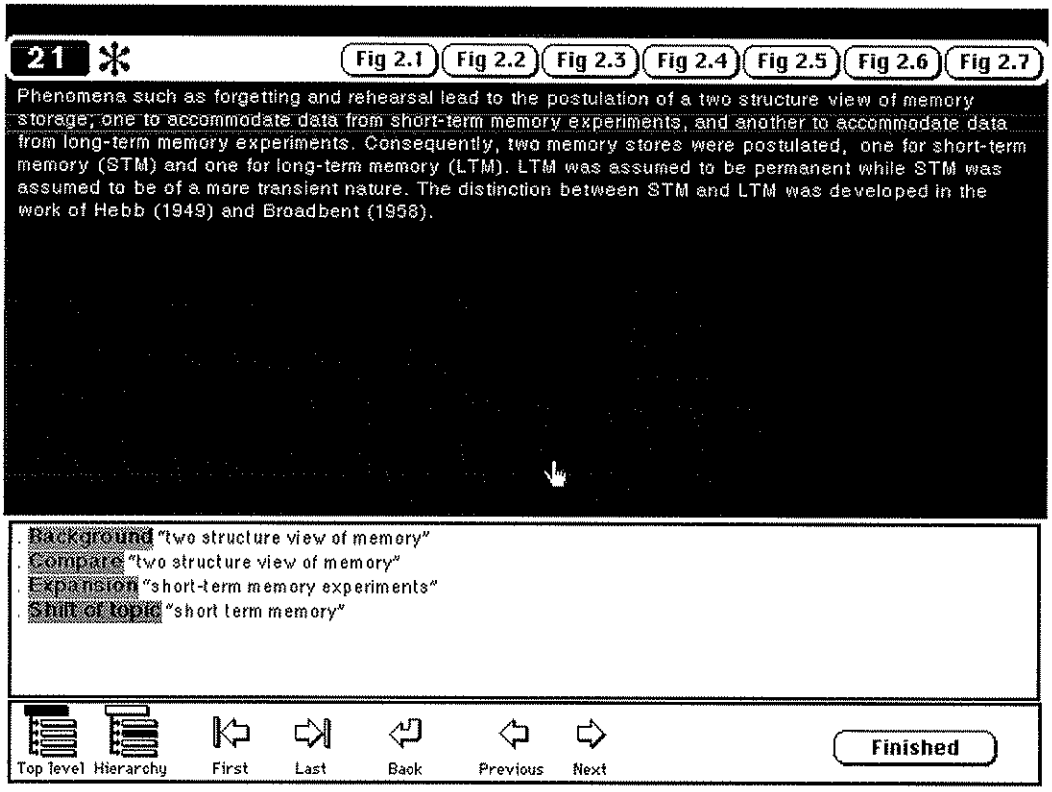


Figure 11: Node 21 in the hypertext. This node can be reached from the first node of the hypertext (fig. 9). Again the links are shown as they would have appeared for subjects in treatment 4.

The questionnaire

The questionnaire given to the subjects before the experiment asked:

1. Whether the subject was a student, and if so, what course they were doing.
   This was asked to ensure that students doing courses which covered the text used in this experiment were distributed evenly over the experimental treatments.
2. (i) Whether they had previously read the text on which the hypertext system was based, (ii) Whether they were familiar with the concept of hypertext, and (iii) Whether they had used a hypertext system before.
   These were asked to test the subjects' prior knowledge of hypertext. Testing their knowledge of the information domain was less important as this was done by asking them to answer questions about the domain both before and after using the hypertext system.

into sections. This was a screen showing how the chapter was divided into sections, or for each section a screen showing how that section was divided into nodes.

The hypertext system had to be specially built rather than built with any hypertext authoring tool, because of the special functionality required of it as an experimental environment. It was built in HyperCard (Apple, 1987), a prototyping system for the Apple Macintosh[12], which enables small, graphically oriented programs to be built and modified quickly. While it can easily be used to display graphics and text, it does not normally display colour. However, since this experiment required colour, a third-party software extension which permitted coloured text was used[13].

The division of text into nodes was made on the same basis as that described in chapter 4, that is, node boundaries were made at paragraph breaks in the text. Occasionally, two paragraphs were put into a single node or a single paragraph was split over two nodes and this process resulted in there being 54 nodes in the hypertext system.

The links were assigned to the text by a detailed inspection of the text and an examination of interrelationships in the text. While care was taken with this process, the resulting network of links in the text cannot be said to be the correct assignment of links to the text. Indeed, the issue of how the correct placing of these links in a hypertext can be known is a topic for future research. Even the notion of what 'correct' link placement is and the extent to which such things as task type and text type affect link placements in a hypertext system are not known.

Thus, there may be errors in the placement of links. Suppose it is assumed though that there are at least enough links correctly placed such that any effect they provide can be tested. Then, because each subject is exposed to the same material, and is asked to perform the same tasks in the hypertext system in the same order, any errors that incorrect placing of the links generate should not affect the results.

The screen presentation was designed so that the text was separated from the links on the screen, with the links shown below it. This was done so that the presentations for the treatments where the link type labels were shown and where they were not shown were as similar as possible in appearance. If the link labels were included in the text, because this would have altered the appearance of the text, such things as reading speed, comprehension and how much people read may have been affected.

The relational links were presented in the form:

---

[12]'Apple' and 'Macintosh' are trademarks of Apple Computer Inc.

[13]Colour Text Package 2.0.1 © 1993 Nigel Perry

[used flag] [link name] [text]

Examples of relational links such as these can be seen in the lower half of figures 9 and 11, and in figure 10.

The [used flag] was either blank, or was a tick, signifying that this user of the hypertext had used that link before.

The [link name] showed the name of the link and was presented in a colour unique to that link name, such that the colours used for different link names were distinctive. If the experimental treatment was one in which the link names were not presented, just a blank coloured strip was used. If colours were not used, the link name or the blank strip was presented in a neutral colour.

The [text] showed, in quotes, the section of text within the node that the link applied to.

When choosing the colours which the link labels would be presented in, it was necessary to choose 12 distinct colours. This was done by choosing 12 colours from a 'colour wheel' so that they were equally spaced around the wheel and yet at the same level of saturation and brightness. These colours were then used to present the text of the link label, and the background on which the link label was presented was of the same colour but at a lower level of saturation.

Procedure

The experimental procedure for subjects from each of the four treatment groups was the same. The differences between the treatments lay in whether the names of the relational links were shown, or the relational links were shown in different colours according to their type, or both. The subjects answered four questions with the aid of a hypertext system which contained these relational links. In addition, before using the hypertext, the subjects were tested with the same questions, and were asked to create their own aliases of the relational link type descriptions.

First, the four questions were answered by the subjects to test their prior knowledge of the answers. These questions were:

1. What is the distinction between short term memory and working memory?
2. How is memory searched - serial or parallel?
3. What happens when people are allowed to recall things in any order?
4. When the items to be recalled are well-known to the subject, how does this affect their recall?

Then the subjects created their own aliases of the relational link types' names. As was said in the previous chapter it was the intention to allow subjects to use their own aliases rather than impose names for them. Subjects were given the descriptions of each of these link types (shown in the instructions given to the subjects in Appendix 6, and also at the end of the previous chapter), and asked to write down a one or two word summary that would embody the meaning of the relationship. These summaries were later used for the screen presentations of the link types. To enable the subjects to remember which descriptions their summaries related to they had access to these descriptions throughout the experiment.

Having done this, they started to use the hypertext system to answer the same four questions (i.e. the same as those above). Always starting at the same node in the hypertext system, they would navigate their way around until they were satisfied that they had found the answer to the question that had been presented to them. They would then write this answer down, press a button on the screen to indicate that they had finished the current question, and would then be taken on to the next question.

The questions were presented to all the subjects in the same order. There may have been some merits in randomising the order of the questions across the subjects, for example to look for learning effects. However, it would have been impossible to take account of the effects of knowledge gained in answering one question on subjects' performance on subsequent questions if the question order was randomised.

Automatic collection of data

Data to do with the usage of the hypertext were collected automatically. These data were a series of time stamps, recording the time at which any of the following events took place:

- The subject started the experiment. Also recorded was the subject's number.
- The subject started a new question. Also recorded was which question number it was.
- The subject used a link in the hypertext. Also recorded was the type of the link if it was one of the relational links, or its name otherwise, and the number of the node the link led to.

1.3. Results

Sources of results

There are three sources of data from which the results of this experiment can be drawn:

1. Questionnaire: Responses to the questionnaire.
2. Written answers: The subjects' answers to the questions, written both before and after using the hypertext system.
3. Navigation data: The data collected automatically as the subject travelled through the hypertext system.

How these categories of data were treated is shown below:

Questionnaire

The information collected was about whether the subject was a student, whether they had read the text contained in the hypertext system before, and whether they were familiar with hypertext and had used hypertext systems before. This was collected because it was known that some of the subjects had expertise in hypertext and some had expertise in the information domain of the hypertext system. Therefore the data were collected to ensure that these subjects were distributed evenly across the four experimental treatments. A summary is shown in table 7, and shows that no treatment received a disproportionate number of students, or of those who were familiar with hypertext or of those who had used a hypertext system before. Treatments 3 and 4 (i.e. those subjects who would be shown the link-type names) received slightly fewer subjects who had read the text before.

	Tr. 1 (control)	Tr. 2 (C)	Tr. 3 (LL)	Tr. 4 (C+LL)
Number of subjects in treatment	8.	8.	8.	8.
Number of subjects who were students	6.	7.	6.	4.
...who had read the text before	4.	3.	1.	2.
...who were familiar with hypertext	5.	4.	4.	6.
...who had used a hypertext system	3.	4.	3.	6.

Table 7: This table summarises the responses to the pre-experiment questionnaire.

Written answers

Each answer was marked to examine the subjects' success at answering the questions before and after using the hypertext system. This was done for two reasons. Firstly, to provide data on any variation in question answering success across the treatment groups, and secondly, so that when looking at data for subjects' navigation in the hypertext system, the question of whether that navigation strategy led them to the right answer can be addressed.

The correct answers for each question were collections of statements from the text of the hypertext. Each statement was given a score (so that each question had a maximum mark of 5) and a subject's score for a question would be the sum of the scores for all the statements which that subject had identified in their answer.

Thus there were two scores for each question answered by each subject, showing the subject's knowledge of the question topic before and after using the hypertext. The difference between these was taken as the effect of the hypertext system on the subject's knowledge.

Navigation data

These data were collected automatically while the subject used the hypertext system, and contains several elements:

- The code assigned to identify that subject
- Each time the subject started looking for the answer to a new question, the number of that question and a time stamp were recorded.
- Each time the subject went from one node to another, this was recorded with a time stamp, the nature of the link between the two nodes and the node that they arrived at. If the link was a relational link, the pair of numbers which identified that link was recorded. This consisted of a number identifying which of the twelve link types the link was, and the node to which that link led. For example the link "10,13" would be a link of

type 10, leading to node 13. If the link was a navigational link, the name of the link (e.g. "Next", "First", etc.) would be recorded.

All these can be seen in the sample shown in table 8 below. Subject "c12" started looking for the answer to question 1 at a time given by the number "2835945738"[14]. This subject followed four relational links, moving from node 1 to nodes 13, 21, 35, and then 36. A "Prev" link was then followed to the node immediately previous in the hypertext system, node 35. The subject continued, eventually finishing on node 3.

Started at: 2835945689	2835946063, «7,36» to 36
	2835946076, Prev to 35
Subject: c12	2835946078, Prev to 34
	2835946080, Prev to 33
2835945738, Question 1	2835946094, first to 1
2835945763, Starting at 1	2835946144, «11,2» to 2
2835945914, «10,13» to 13	2835946176, «7,3» to 3
2835945967, «10,21» to 21	2835946200, «1,31» to 31
2835946031, «11,35» to 35	2835946223, «2,3» to 3

Table 8: Transcript of subject "c12"'s use of the hypertext.

These data, such as is shown in table 8, can be analysed to show the factors that were listed in section 1.2, for each question answered by each subject:

- The number of nodes or links used (n). This figure can be split up to show the number of navigational links used (Nn) and the number of relational links used (Rn). Thus, n=Rn+Nn
- The time taken (t). Again this can be split up to show the time spent on nodes before following navigational links (Nt) as opposed to the time spent on nodes before following relational links (Rt); thus, t=Nt+Rt. It would be more accurate to say that no time at all is spent actually following links, as once the subject has selected a link, the link's destination is presented almost instantaneously. What these (Nt and Rt) mean is the time the subject spent reading the text of a node before following either navigational or relational links. These measures were collected to look at differences in the times spent reading nodes before following either navigational or relational links.
- The ratio of navigational to relational links used (Rn/n). To determine how readily subjects used the relational links, as opposed to the navigational links, the numbers of navigational and relational links used can be

[14]This number is the number of seconds since midnight, 1st January 1904. The time is provided like this by a function in HyperCard. It can easily be seen that this particular number corrresponds to a Friday morning in early November, 1993.

separated, and either one looked at as a proportion of the total number of links used.

- Also, looking at the results, it became clear that 'series' of links were used. A 'series' here means that either the "Next" or "Previous" link type is used repeatedly to move forward or backwards through the hypertext. This suggests that the subject, rather than using the network properties of the hypertext is simply moving through the text linearly in search of their goal, in much the same way as they might with a linear, paper-based text. For a large, paper-based text this would of course be an inefficient strategy, and similarly, would be an inefficient strategy in a large hypertext system too. It only worked in this case because the hypertext system was relatively small and the subject knew that the answers fell within the hypertext. If the hypertext system was large, and the subjects did not know that it necessarily contained the answers they were looking for it is less likely that they would apply such a strategy.

  The number of link traversals taken up in series of either "Next" or "Previous" links is denoted by Sn.

Tests of the experimental hypotheses

The effects that it was hypothesised would result from the presence of the relational links are shown below. With each of these is shown the sources of data that were examined.

(a) Subjects would preferentially use the relational links.

For this, features of the navigational data that were examined were:

(i) The proportion of relational links to the total number of links used (Rn/n).

(ii) The total number of links used (n).

(iii) The number of relational links used (Rn).

(iv) The number of navigational links used (Nn).

(b) Subjects would answer the questions more accurately.

For this, the differences between the scores achieved by the subjects before and after using the hypertext system were examined (Postscore-Prescore).

(c) Subjects would answer the questions faster.

The times taken by the subjects to answer the questions (t) was examined. These times were also separated out by the scores achieved (Postscore-

Prescore) as well. This measured the way that the times required to achieve certain scores varied across treatments.

ANOVAs were done to determine the significance of these effects in the data. These are summarised in Appendix 7. The results presented here are summaries of Tukey's method for multiple comparisons performed on the ANOVA data.

First, the methods for deriving the data shown in this section, and the manner in which they are organised will be explained. The four experimental treatments will be referred to in this section by their associated numbers and by the labels in italics. These treatments were listed above in section 1.2, and are shown again here as a reminder:

1. *{control}* Subjects were shown all link types the same colour, with the link type labels not displayed (the 'control' treatment).
2. *{C}* Subjects were shown each link type assigned a different colour, with the link type labels not displayed.
3. *{LL}* Subjects were shown all link types the same colour, with the link type labels displayed.
4. *{C+LL}* Subjects were shown each link type assigned a different colour, with the link type labels displayed.

In each of the tables of Tukey test results the labels showing the meanings of the treatments are given. Treatment 1 is *{control}*, treatment 2 is *{C}* (the "C" stands for "Colour"), treatment 3 is *{LL}* (the "LL" stands for "Link Labels"), and treatment 4 is *{C+LL}*.

Table 9 is a summary of the Tukey test results for (Rn/n). It shows the means for the four treatments, the pairwise differences that must be calculated (e.g. μ_1-μ_2), and then what those pairwise differences are (in the column "y_i-y_j"). The column "Tukey Interval" then shows the two values $(y_i-y_j)\pm D\sqrt{MSE}$, where MSE is the Mean Squared Error arising from the ANOVA.

$D=Q_{\alpha,k,rk-k}/\sqrt{r}$, where r is the sample size (in this case 8), k is the number of treatments (4), and $Q_{\alpha,k,rk-k}$ is the studentised range value for the level of significance α (α=0.05 in all these analyses). Finally, the column "Conclusion" tests whether the value 0 lies in the Tukey interval. If it does not, the null hypothesis (H_0: $\mu_i=\mu_j$) can be rejected in favour of (H_1: $\mu_i\neq\mu_j$) at the α level of significance. This column shows whether the null hypothesis is accepted or rejected.

These conclusions can then be represented as a series of numbers, thus: $\overline{2143}$. This summarises the results for (Rn/n) and shows the ordering of the means of the four treatments, from lowest to highest, and the bar above the first three numbers indicates

that those treatment's means are not significantly different from each other and that treatment 3's mean is significantly different from the rest.

The chart shown in fig. 12 shows the variation of Rn/n over the four treatments (Tr. 1 ... Tr. 4), and within these treatments over the four questions (Qu. 1 ... Qu. 4).

The format of the results and the method of their derivation is the same for all results in this section.

Preferential usage of relational links

The first hypothesis was that subjects would preferentially use the relational links when the relational link labels were shown. Each measurement that has a bearing on this hypothesis will be examined, and then their combined result will be discussed.

Treatments Means (y_n).	*Pairwise difference*	y_i-y_j	*Tukey Interval*	*Conclusion*
{control}1 0.261	μ_1-μ_2	0.048	(-0.102, 0.198)	Accept
{C} 2 0.213	μ_1-μ_3	-0.284	(-0.434, -0.135)	Reject
{LL} 3 0.546	μ_1-μ_4	-0.068	(-0.218, 0.082)	Accept
{C+LL} 4 0.329	μ_2-μ_3	-0.333	(-0.483, -0.183)	Reject
	μ_2-μ_4	-0.117	(-0.266, 0.033)	Accept
$D\sqrt{MSE}$= 0.15	μ_3-μ_4	0.216	(0.066, 0.366)	Reject

Table 9: Tukey test results for Rn/n (α=0.05). The full Anova is in Appendix 7.1.

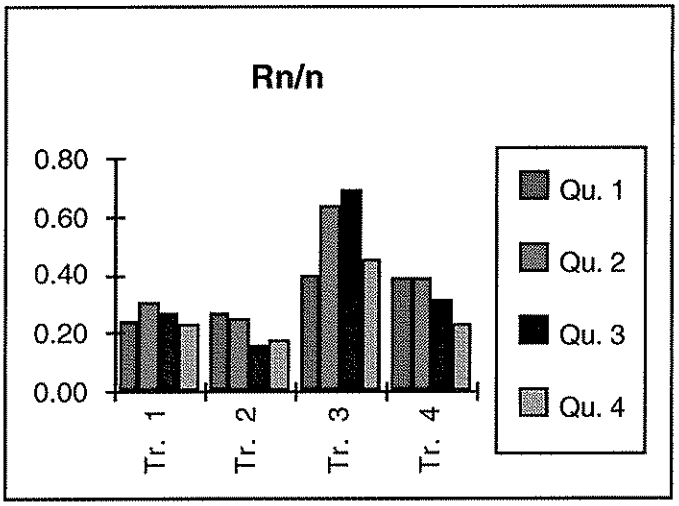


Figure 12: Chart of Rn/n values against treatments (Tr. 1 ... Tr. 4)

The proportion of relational links used to total number of links used (Rn/n) was examined and the results of this are shown in table 9, and fig. 12. Subjects in treatment 3 used a significantly greater proportion of relational links than subjects in the other treatments, and the Tukey test can be summarised as ($\overline{2143}$). Treatment 4, the other treatment in which the link labels were shown did not show a significantly greater

usage of relational links, but it can be seen that there was some increased usage of relational links in that treatment.
This suggests that the presence of the relational link labels caused subjects to make more usage of the relational links.

The figures which make up the proportion (Rn/n) discussed above will now be looked at, to see what made the proportion change. These are n, Rn and Nn.

Treatments Means (y_n)	*Pairwise difference*	y_i-y_j	*Tukey Interval*	*Conclusion*
{control}1 31.438	μ_1-μ_2	14.	(2.219, 25.781)	Reject
{C} 2 17.438	μ_1-μ_3	9.844	(-1.937, 21.625)	Accept
{LL} 3 21.594	μ_1-μ_4	12.813	(1.031, 24.594)	Reject
{C+LL} 4 18.625	μ_2-μ_3	-4.156	(-15.937, 7.625)	Accept
	μ_2-μ_4	-1.188	(-12.969, 10.594)	Accept
$D\sqrt{MSE}$= 11.781	μ_3-μ_4	2.969	(-8.812, 14.75)	Accept

Table 10: Tukey test results for n (α=0.05) The full Anova is in Appendix 7.2.

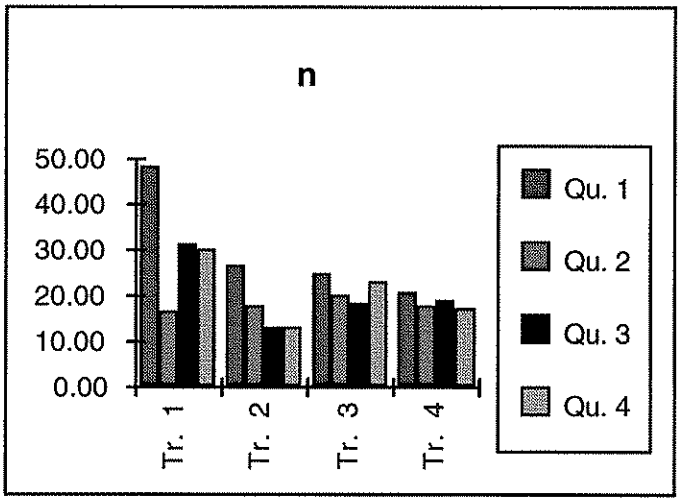


Figure 13: Chart of n values against treatments (Tr. 1 ... Tr. 4)

First n, the total number of links will be examined (table 10 and fig. 13). There was little change in n across the treatments except in treatment 1 whose subjects used significantly more links than those in treatments 2 or 4. The Tukey test gives ($\overline{2431}$).

Looking at Rn (table 11 and fig. 14), subjects in treatment 3 used more Relational links than those in other treatments although only significantly more than those in treatment 2.

Treatments Means (y_n)	*Pairwise difference*	y_i-y_j	*Tukey Interval*	*Conclusion*
{control}1 7.469	μ_1-μ_2	3.094	(-1.771, 7.959)	Accept
{C} 2 4.375	μ_1-μ_3	-2.625	(-7.49, 2.24)	Accept
{LL} 3 10.094	μ_1-μ_4	1.219	(-3.646, 6.084)	Accept
{C+LL} 4 6.25	μ_2-μ_3	-5.719	(-10.584, -0.854)	Reject
	μ_2-μ_4	-1.875	(-6.74, 2.99)	Accept
$D\sqrt{MSE}$= 4.865	μ_3-μ_4	3.844	(-1.021, 8.709)	Accept

Table 11: Tukey test results for Rn (α=0.05). The full Anova is in Appendix 7.3.

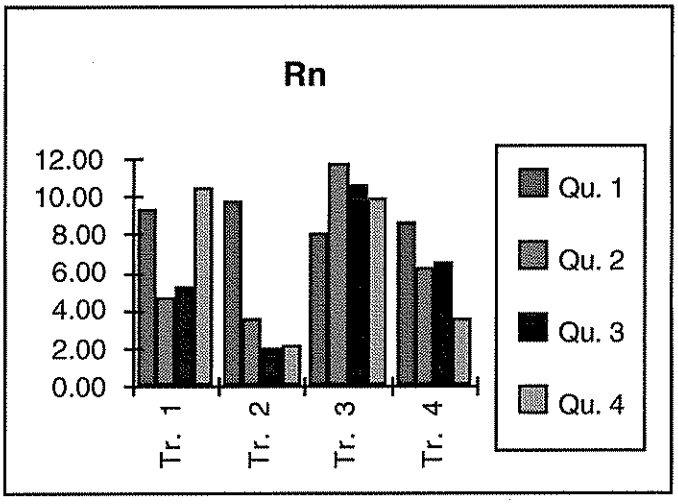


Figure 14: Chart of Rn values against treatments (Tr. 1 ... Tr. 4)

The Tukey test gives ($\overline{2413}$). Subjects in treatment 1 appear to have used a large number of relational links considering that they did not have the link labels presented, but it must be remembered that they used significantly more links overall.

Looking at the analysis for Nn (table 12 and fig. 15) it can be seen that only those subjects in treatment 1 used significantly more navigational links than those in other treatments (The summary of the Tukey test gives $\overline{3421}$). Subjects in treatments 3 and 4 used fewest navigational links, although not by a significant amount when compared to subjects in other treatments.

Treatments Means (y_n)	*Pairwise difference*	y_i-y_j	*Tukey Interval*	*Conclusion*
{control}1 23.969	μ_1-μ_2	10.906	(0.97, 20.842)	Reject
{C} 2 13.063	μ_1-μ_3	12.469	(2.533, 22.405)	Reject
{LL} 3 11.5	μ_1-μ_4	11.594	(1.658, 21.53)	Reject
{C+LL} 4 12.375	μ_2-μ_3	1.563	(-8.373, 11.498)	Accept
	μ_2-μ_4	0.688	(-9.248, 10.623)	Accept
$D\sqrt{MSE}$= 9.936	μ_3-μ_4	-0.875	(-10.811, 9.061)	Accept

Table 12: Tukey test results for Nn (α=0.05). The full Anova is in Appendix 7.4.

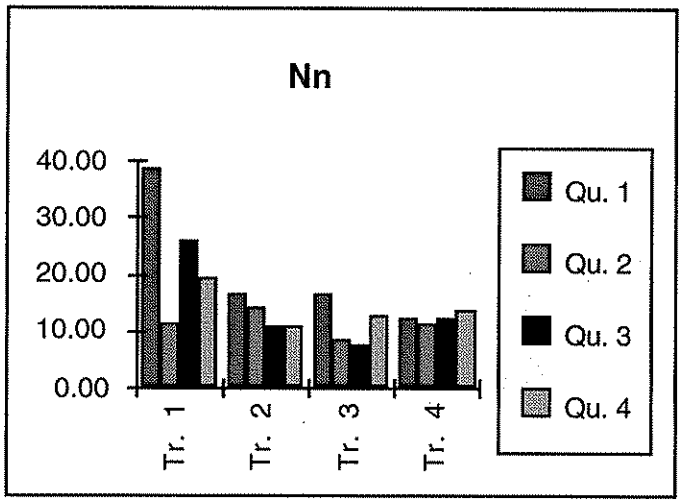


Figure 15: Chart of Nn values against treatments (Tr. 1 ... Tr. 4)

So, to summarise these analyses, treatment 3, the treatment in which relational link labels, but not colours, were shown will be looked at first. When compared to the other treatments, subjects in this treatment used significantly more relational links and a similar total number of links compared to subjects in other treatments (except for the control treatment, which used significantly more). For these subjects, the proportion of the number of relational links used to the number of links used in total was significantly higher. This, combined with the slight reduction of navigational links used when compared to the rest of the treatments suggests that they were using relational links preferentially to navigational links. For treatment 4, in which the link labels were shown and the different link types were differentiated by colour, these effects were also present, but were not so marked, and were not significant.

Accuracy of question answering

As was discussed earlier the subjects completed the questions not only after they had found the answers in the hypertext, but also beforehand, to assess their prior

knowledge. The completed subjects' answered were marked, as was described before, and each given a score between 0 and 5. The mean and standard deviation of all the subjects' scores are shown below in table 13, for the four questions they had to answer, before and after using the hypertext, and the means and standard deviations of the differences between the scores is also shown.

		Scores before using hypertext (the "Prescore")					*Scores after using hypertext (the "Postscore")*					*(Scores after...) - (Scores before...)*				
		Qu. 1	*Qu.2*	*Qu.3*	*Qu.4*	*Qus. 1, 2, 3 & 4*	*Qu.1*	*Qu.2*	*Qu.3*	*Qu.4*	*Qus. 1, 2, 3 & 4*	*Qu.1*	*Qu.2*	*Qu.3*	*Qu.4*	*Qus. 1, 2, 3, 4*
Tr. 1 (control)	*Mean*	0.8	0.0	0.6	0.9	0.6	2.1	2.5	2.0	2.4	2.3	1.4	2.5	1.4	1.5	1.7
	S.D.	1.0	0.0	1.2	0.8	0.9	1.6	1.8	1.1	0.7	1.3	1.9	1.8	1.4	1.1	1.6
Tr. 2 (C)	*Mean*	0.9	0.3	1.3	1.1	0.9	2.8	2.6	1.8	2.0	2.3	1.9	2.4	0.5	0.9	1.4
	S.D.	1.6	0.7	1.5	0.8	1.2	0.9	1.1	1.0	1.2	1.1	1.4	0.9	0.9	1.4	1.3
Tr. 3 (LL)	*Mean*	0.3	0.0	1.1	0.8	0.5	3.0	2.6	2.8	3.1	2.9	2.8	2.6	1.6	2.4	2.3
	S.D.	0.7	0.0	0.8	0.7	0.8	1.2	1.6	0.9	1.1	1.2	1.6	1.6	1.1	1.1	1.4
Tr. 4 (C+LL)	*Mean*	0.0	0.0	0.5	0.8	0.3	2.4	2.8	2.6	2.5	2.6	2.4	2.8	2.1	1.8	2.3
	S.D.	0.0	0.0	0.9	0.5	0.6	1.6	1.0	0.7	0.5	1.0	1.6	1.0	1.5	0.7	1.2
Tr. 1, 2, 3 & 4	*Mean*	0.5	0.0	0.9	0.9	0.6	2.6	2.6	2.3	2.5	2.5	2.1	2.6	1.4	1.6	1.9
	S.D.	1.0	0.4	1.1	0.7	0.9	1.3	1.3	1.0	0.98	1.2	1.6	1.3	1.3	1.2	1.4

Table 13: Means and standard deviations (S.D.) for the question scores. These are shown for the questions answered both before and after using the hypertext system, and for the difference between these scores. The minimum score was 0, and the maximum score was 5.

The Standard Deviations of the scores do not vary greatly except where the score is zero or very low. Here, the Standard Deviation is lowered by several subjects all scoring zero.

Before using the hypertext, subjects' scores on the questions were, as might be expected, lower than their scores after using the hypertext. After using the hypertext, subjects in treatments 3 *(LL)* and 4 *(C+LL)* achieved higher scores than subjects in treatments 1 *(control)* and 2 *(C)*, and the greater improvement seen in these subjects' scores is also reflected in the differences between the scores.

Rather than the actual scores, reflecting subjects' knowledge of the material in the hypertext either before or after using it, this experiment is more concerned with the improvement in the subjects' knowledge brought about by use of the hypertext, and how this improvement varies with features of the hypertext links. To measure an improvement in the subjects' ability to answer the questions, the difference between the scores achieved before and after using the hypertext was taken. These scores are

shown on the right hand side of table 13 above. A high score here represents a large improvement between answering the question before and after using the hypertext.

Treatments Means (yn)	*Pairwise difference*	*yi-yj*	*Tukey Interval*	*Conclusion*
{control}1 1.688	μ1-μ2	0.281	(-0.581, 1.144)	Accept
{C} 2 1.406	μ1-μ3	-0.656	(-1.519, 0.206)	Accept
{LL} 3 2.344	μ1-μ4	-0.563	(-1.425, 0.3)	Accept
{C+LL} 4 2.25	μ2-μ3	-0.938	(-1.8, -0.075)	Reject
	μ2-μ4	-0.844	(-1.706, 0.019)	Accept
$D\sqrt{MSE}$= 0.862	μ3-μ4	0.094	(-0.769, 0.956)	Accept

Table 14: Tukey test results for (Postscore-Prescore)(α=0.05). The full Anova is in Appendix 7.5.

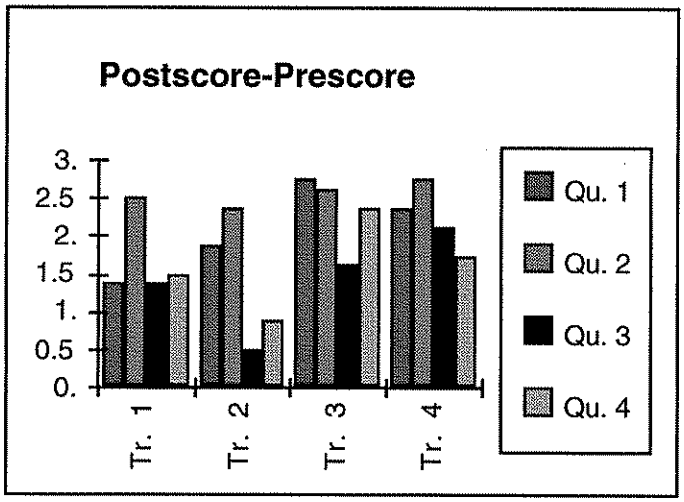


Figure 16: Chart of (Postscore-Prescore) values against treatments (Tr. 1 ... Tr. 4)

The (Postscore-Prescore) measure was found to vary significantly across treatments, and table 14 and fig. 16 show the Tukey test results and the chart for (Postscore-Prescore). The Tukey test results can be summarised as ($\overline{2143}$). This shows that subjects in treatments 4 and 3 scored more than those in treatments 2 and 1, with the difference in scores between subjects in treatments 3 and 2 being significant. Treatments 3 and 4 were those in which the relational link labels were displayed, so this suggests that the relational links allow subjects to achieve greater improvements in their scores.

There were only small differences in the scores obtained for question 2 across the treatments. As was discussed in section 1.2 the number of nodes that needed to be visited to obtain a 'complete' answer varied across the questions, with question 2 requiring only 1 node to be visited (The complete answers for questions 1 and 3 were

spread over four nodes, and question 4's over 5 nodes). It can be inferred from this that the relational link types are of greater benefit when the user has to visit several places to assemble a complete answer.

Time taken to answer questions

Across the treatments, there were no significant differences between the times taken to answer questions (t).

Treatment	*Qu. 1*	*Qu. 2*	*Qu. 3*	*Qu. 4*	*Mean*
{control}1	834	308	382	376	475
{C} 2	582	269	206	191	312
{LL} 3	581	450	341	294	416
{C+LL} 4	600	356	359	258	393

Table 15: Mean values for t, showing values by treatment and by question, and the means for the treatments. The full set of data is in Appendix 7.6.

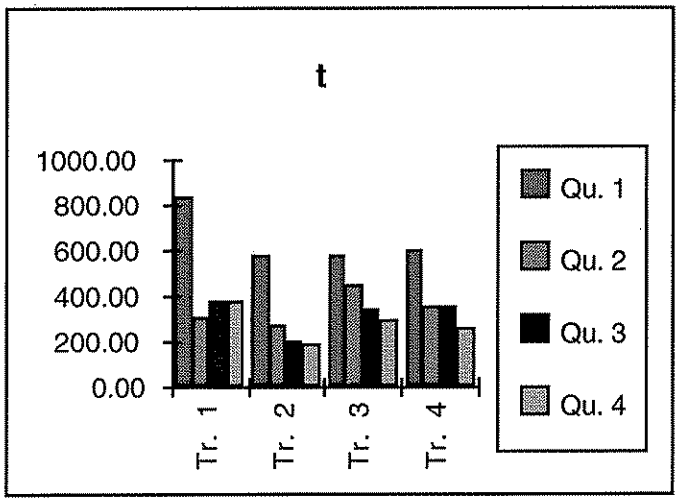


Figure 17: Chart of t against treatments (Tr. 1 ... Tr. 4)

The table and chart of means for t for the four treatments and the four questions (table 15 and fig. 17) show that there was little change over the treatments. They do show that generally there was a decrease in the time taken to answer questions over the four questions, possibly indicating a learning effect. This cannot be definitely concluded though, because of the considerable differences between the questions.

There was some evidence that the times taken to achieve similar scores varied across treatments. In table 16 and fig. 18 below are shown the average times taken to achieve scores of between -1 and 5 by subjects in the four treatments. Scores of -1 were

achieved by subjects answering the questions worse after using the hypertext than they did before. The scores of -1, 0, 1, 2, 3, 4 and 5 were achieved 5, 18, 23, 40, 25, 12 and 5 times respectively, adding up to 128 scores (from 32 subjects answering 4 questions each).

'Score' here means, as before, the difference between the score achieved on the question before using the hypertext and the score achieved after using the hypertext.

	Treatment 1 {control}		*Treatment 2 {C}*		*Treatment 3 {LL}*		*Treatment 4 {C+LL}*	
Score: -1.	164	(1)	327	(3)	0	(0)	233	(1)
0.	568	(10)	221	(5)	612	(2)	273	(1)
1.	224	(3)	204	(8)	291	(7)	361	(5)
2.	417	(7)	368	(10)	500	(11)	429	(12)
3.	505	(7)	344	(4)	351	(4)	264	(10)
4.	575	(3)	604	(2)	359	(6)	354	(1)
5.	608	(1)	0	(0)	502	(2)	1066	(2)

Table 16: Mean values for t, showing values by treatment and by scores achieved on questions. The figures in brackets show the number of subjects who achieved a particular score on a particular question. For example in treatment 2, 5 subjects achieved a score of 0, and the average of the times they took to do this was 221.4 seconds.

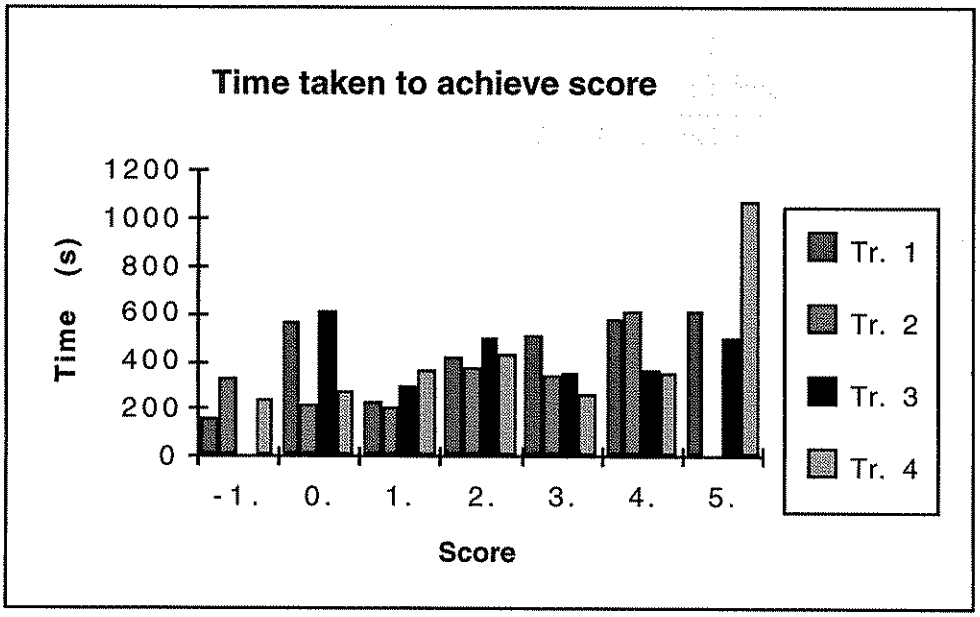


Figure 18: This chart shows for scores achieved by the subjects in the four treatments (Tr. 1 ... Tr. 4), how long it took them to answer.

What table 16 and fig. 18 suggest is that those subjects with access to the relational link types (treatments 3 and 4) could achieve scores of 3 and 4 without taking substantially more time to do so. The times taken to achieve scores of 5 and -1 are difficult to assess, because they were achieved by very few subjects overall and in some treatments, no subjects.

Caution must be observed when looking at all these results. There was considerable variation in the times recorded for individual subjects, and in the numbers of subjects in any given treatment group achieving a certain score.

Usage of 'series' of links

'Series' of navigational links refer to when subjects repeatedly used either the "Next" or "Prev" links to move forwards or backwards through the linear representation of the text. By doing this, the subject is moving linearly through the hypertext; this is analogous to looking through a book from start to finish in search of something. This is of course usually an inefficient strategy for searching for information, but may have been used here because the subjects knew (a) that the hypertext was not so large that looking at every node would take a prohibitively long time, and (b) that the information for which they were searching was definitely in the hypertext somewhere. Had the hypertext been large or if there was some doubt in the subject's mind as to whether it contained the information they were looking for, it is likely that this searching strategy would not have been used so much. This strategy of link usage was also discussed earlier in this chapter.

For each question answered by each subject, the number of link traversals made which formed part of a series was measured. This number (Sn) was found to vary significantly across treatments.

Treatments Means (yn)	*Pairwise difference*	*yi-yj*	*Tukey Interval*	*Conclusion*
{control}1 10.75	μ1-μ2	6.969	(0.626, 13.312)	Reject
{C} 2 3.781	μ1-μ3	6.281	(-0.062, 12.624)	Accept
{LL} 3 4.469	μ1-μ4	5.656	(-0.687, 11.999)	Accept
{C+LL} 4 5.094	μ2-μ3	-0.688	(-7.031, 5.656)	Accept
	μ2-μ4	-1.313	(-7.656, 5.031)	Accept
D√MSE= 6.343	μ3-μ4	-0.625	(-6.968, 5.718)	Accept

Table 17: Tukey test results for Sn (α=0.05). The full Anova is in Appendix 7.7.

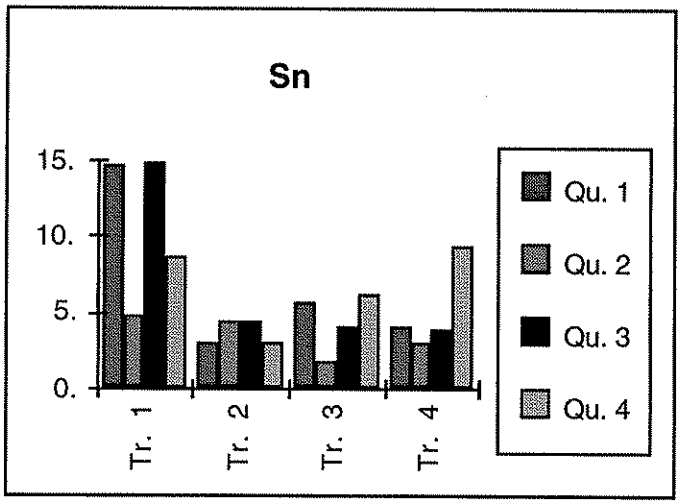


Figure 19: Chart of Sn against treatments (Tr. 1 ... Tr. 4)

Table 17 and fig. 19 show the Tukey test results and the chart showing the variation of Sn over treatments and over questions. The Tukey test can be summarised as ($\overline{2341}$), and shows only that treatment 2 is significantly different from treatment 1.

The variation in the use of these series between treatments is possibly masked by the large degree of variability between subjects. For this reason the series of links used by individual subjects were examined, and these are shown in fig. 20 below. Fig. 20 shows each subject, and for each subject a number of vertical bars, each one representing each series of links that subject used. The height of the bars indicates the length of the series, that is the number of consecutive uses of the "Next" link or the number of consecutive uses of the "Prev" link. The subjects are arranged in their four treatment groups to enable these treatments to be compared.

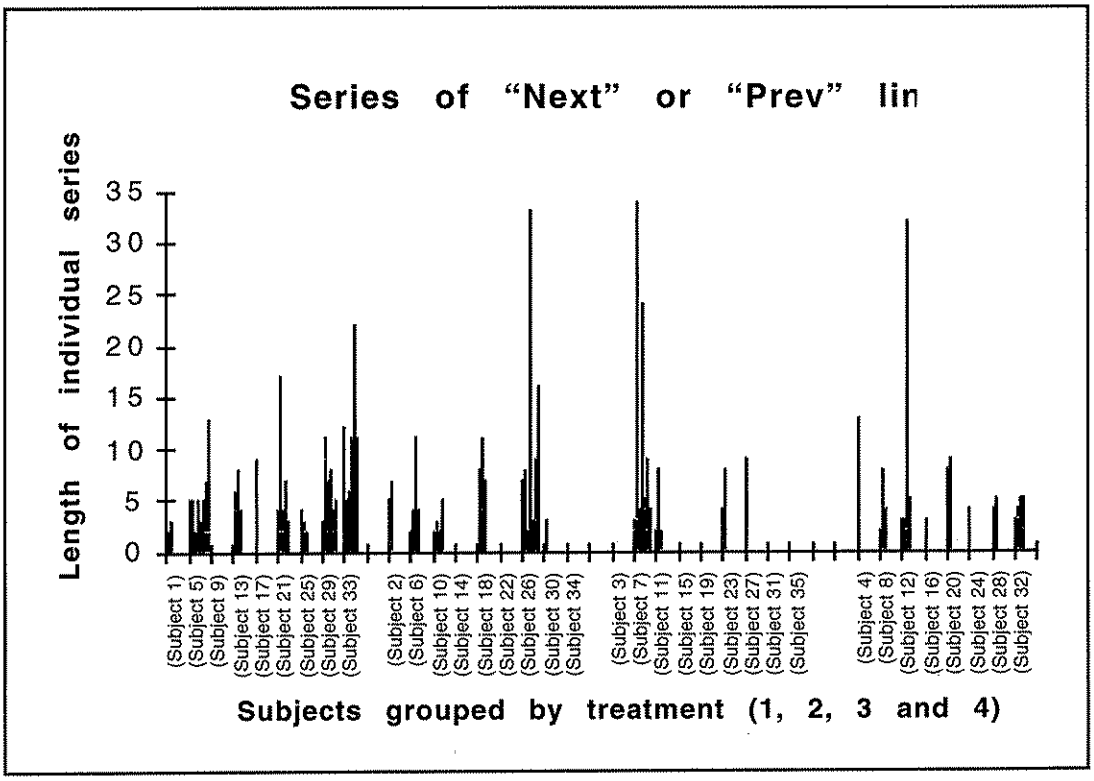


Figure 20: Chart of all link series against subjects

Fig. 20 shows that there was a great deal of variation across subjects with some subjects (e.g. subjects 5, 29, 33, 26, and 7) using very many series, and other subjects (e.g. subjects 14, 22, 34, 3, 15, 19, 31, and 35) using none. What stands out is that in treatment 3, most subjects used no series of links, and those that were used in that treatment were used mainly by one subject (subject 7). This suggests that those subjects had less need to resort to this strategy of searching through the hypertext. Subjects in treatment 4, in which subjects had access to the link labels and had the links distinguished by colour did not perform as well as subjects in treatment 3 in this respect.

This data will not be subjected to statistical analysis or analysed further, because (a) the differences in the use of series of links are large and self-evident, and (b) the experiment was not designed to explore navigation strategies and so firm conclusions cannot be drawn from this data.

1.4. Discussion

The results of each of the statistical analyses can be summarised thus:

- Rn/n (The ratio of relational links used to the total number of links used): This ratio showed that subjects in treatment 3 and 4 (*{LL}* and *{C+LL}*) used a greater proportion of relational links than subjects in other treatments,

subjects in treatment 3 using a significantly greater proportion than those in any other treatment.

- n (The total number of links used): Subjects in treatment 1 (*{control}*) used the greatest number of links overall, significantly more than those in treatments 2 and 4 (*{C}* and *{C+LL}*).
- Rn (The number of relational links used): Subjects in treatment 3 (*{LL}*) used the greatest number of relational links. Those subjects in treatment 2 (*{C}*) used the least, and the difference between these two was significant.
- Nn (The number of navigational links used): Subjects in treatment 1 (*{control}*) used significantly more navigational links than subjects in any other treatment.
- The scores achieved on the questions before and after using the hypertext: Looking at the improvement in score between, subjects in treatment 3 (*{LL}*) achieved the greatest improvement, although this was only significantly better than that achieved by subjects in treatment 2 (*{C}*).

  In addition, subjects using the relational link types seemed to show a greater improvement in score on the questions where more than one node needed to be visited to assemble a 'complete' answer.
- The time taken to answer the questions: There was little change over the treatments of the time subjects took to answer the questions.

Two other things were looked at; the usage of 'series' of links, and the way the time taken to answer the question varied with the score eventually achieved:

- The number and length of the series of "Next" and "Prev" links used varied considerably across subjects, with subjects in treatment 3 (*{LL}*) apparently being least willing or finding it least necessary to use this searching strategy.
- There was some evidence to suggest that subjects in treatments 3 and 4 (*{LL}* and *{C+LL}*) did not take as long to achieve a good score as those in treatments 1 and 2 (*{control}* and *{C+LL}*).

The results can be summarised thus: When the subjects were shown the labels describing the meanings of the relational links (these labels showing the subjects' aliases for the descriptions of the relational links) the following was observed:

1. Subjects used more relational links and less navigational links
2. Subjects showed a greater improvement in ability to answer questions on material in the hypertext.
3. There was no significant change in the time taken to answer the questions.
4. There was a reduction in the number of subjects who used 'series' of links.

The way in which these results either confirm or deny the hypotheses stated at the start of this chapter will be looked at first. Then the implications the results have for the thesis as a whole will be examined.

What was being tested was whether use of the relational link types would give subjects some usability advantage or allow them to use the hypertext more efficiently than subjects who did not have access to the relationship types. This was expressed as the hypotheses that:

(a) Subjects would preferentially use the relational links.

(b) Subjects would answer the questions more accurately.

(c) Subjects would answer the questions faster.

The first two of these hypotheses were confirmed, with subjects apparently using a greater number of relational links at the expense of navigational links, and achieving higher improvements in their question scores. However both these effects, although present in both of the treatments which had access to the relationship types were only significant in treatment 3, those subjects who were shown the relationship types' labels but did not have them differentiated by colour. This suggests that differentiating the relationship types by colour, rather than acting as an aid to distinguishing them, interfered with their use. This is backed up by comparing the data obtained for subjects in treatments 1 *{control}* and 2 *{C}*. Like treatments 3 *{LL}* and 4 *{C+LL}*, one of these treatments had the links differentiated by colour and the other did not. Again, like treatments 3 and 4, treatment 2 (the treatment which had the colours) achieved lower scores and used a lower proportion of link types than those in treatment 1. Firm conclusions about the role of colour in hypertext links cannot be drawn however, because whatever effect there may be could be dependent on other factors such as the task and other interface components. Also, allowing subjects to choose their own sets of colours or to spend time learning the associations between the colours and the relationship types may have made them more useful.

The last of these hypotheses, that there would be a reduction in the time taken, could not be demonstrated. However, there was some evidence that the time subjects in treatments 3 and 4 took to achieve a score did not increase with the score achieved as it did with those subjects in treatment 1 and 2. The data that support this do not allow very definite conclusions to be drawn. However, it suggests that for those subjects with access to the link types' labels, while there was not a significant reduction in the times taken to answer the questions overall, there may be a time advantage for those subjects who answered the questions correctly.

Finally, the finding that subjects who had access to the relational links' labels used less 'series' of links suggests that these subjects found the relational links more useful than did other subjects and so did not need to use the searching strategy of sequentially looking at every node in turn until the right node is reached.

Taken together, these results show that subjects chose to use the relational link types when they were available and found that they allowed a higher degree of success in searching for information than other linking methods.

One of the features of the set of relational link types that was hypothesised at the beginning of this chapter was that they should permit more efficient usage of the hypertext system than other linking methods. Because of the differing needs of different hypertext users, 'efficiency' was only loosely defined as allowing a reduction in the effort needed to achieve a certain result, or an improvement in the quality of the results without a greater expenditure of effort. Using the second of these definitions, the relational link types have certainly shown themselves to allow more efficient use of the hypertext system; without taking any more time than subjects in other treatments, subjects who had access to the relational links achieved higher scores than those that did not, the difference being significant between treatments 3 (*{LL}*) and 2 (*{C}*).

In chapters 2 and 3, hypertext was described as lacking definition on anything but a simple level. Hypertext links were described as being either so simple as to provide little help and cause navigation problems, or complex but incurring large authoring costs and with associated problems of inconsistency and understandability. The importance of this experiment for the thesis as a whole is that it has demonstrated that links can be descriptive and complex, such that they assist users, and yet also such that they form part of a general-purpose, well-defined, reusable set.

The next step, having identified a set of relationship types (in the previous chapter), and examined the usefulness of these relationship types, is to look at the mechanism which, it was hypothesised, would make them useful in a hypertext system. This mechanism, expectation, was discussed in chapter 3. In the experiments to derive the relationships in chapter 4, a relationship was defined as something that would allow some expectation of the piece of text that it linked. The next experiment here tests whether the relationships do give their users this expectancy.

2. EXPERIMENT 2.2

2.1. Purpose of the experiment

It will be remembered from chapter 3 that the purpose of the relationship types was to provide a benefit by giving the user some expectation of what text they led to. Then the set of relationship types was developed such that they would provide this expectation. In chapter 4 the relationship types were derived from observations of what relationships were seen in texts, and in these observations a relationship was defined as something that would permit expectation of what text lay at the end of the relationship.

The previous experiment examined the primary requirement that this set of relationship types fulfil, that they provide some measurable benefit to the user in actual hypertext usage. This experiment examines the aspect of the relationship which it was hypothesised would improve their usability, that is, their ability to provide expectation.

2.2. Method

Design

This experiment is to test the links' ability to consistently induce expectation of what text is linked to.

In contrast with the previous experiment, in this experiment there is no point in varying either the exposure to names or colours. The experiment is to test the effect links have on subjects' expectation, and the only reason there might be for varying exposure to link names or colours might be to examine whether those subjects exposed to the link names and colours in experiment 2.1 had been able to learn the links' meanings and associate the meanings with the colours, or whether those subjects exposed to only the colours in experiment 2.1 had been able to infer the meanings of the links. However these tests are not central to this thesis and were not done.

Three possible methods for this experiment are considered, the first providing unstructured answers, and the second and third asking subjects to choose from a set of options:

1. Present subjects with a piece of text and some labelled links leading from the text. Then, for particular links, ask subjects "What's coming at the end of this link?" and allow the subjects to write down their responses.

2. Present subjects with two pieces of text, labelled 'A' and 'B', and a variety of links which could be placed between the pieces of text. Then ask the subjects "Which, out of these links would you follow to get from A to B?".
3. Present subjects with a piece of text, a single link leading from that piece of text, and a variety of pieces of text which that link could lead to. Then ask the subjects, for each piece of text, "Is this what you expected to follow the combination of the paragraph and link?".

It was thought that the first of these methods, because of the informal nature of the responses, would result in data that would be too hard to compare across subjects, and so this method was rejected. The second method was also rejected, because it does not directly test expectancy, but consistency of link authoring.

The last of the three methods above was adopted. The subjects were presented with a *prompt* paragraph, and a link name. Then they were presented with a number of other *target* paragraphs, returning to the prompt paragraph and the link between each. When presented with each target paragraph they were asked "Is this paragraph what you expected to follow the combination of the previous paragraph and link?". Examples of screens used in the experiment are shown in figs. 21 and 22. Fig. 21 shows the prompt screen with the paragraph at the top, followed by the link and the instruction to continue. Fig. 22 shows one of the target paragraphs, with buttons to enable the user to select "Yes" or "No". A "Don't know" choice was not included as it was the intention of the experiment, rather than for the subject to judge whether the two paragraphs were linked or not, to say whether the target paragraph(s) were what the subject had expected. Whereas if the subjects were performing some judgement of the connectedness of the two paragraphs they might not be sure, it was thought that a simple Yes/ No option was all that was needed to allow the subjects to say if the target paragraph was what they had expected.

The method then can be summarised as follows:

1. Subjects are shown the prompt paragraph and link. Subject clicks "Continue" button.
2. Subjects are shown one of the target paragraphs. Subject clicks "Yes" or "No" in response to the question "Is this paragraph what you expected to follow the combination of the previous paragraph and link?". Go back to step 1 (If all the target paragraphs for this prompt paragraph have been shown, change the prompt paragraph and link. If all the sets of prompt and target paragraphs have been shown, the experiment ends).

In order that the link type used could direct subjects' expectation, it was important that each of the items in the testing set were able to be linked to the prompt paragraph. Care therefore had to be taken in the choosing of the prompt paragraph texts for this experiment so that they could be sensibly linked to a variety of other paragraphs which would be used as the target paragraphs. This need for the text to have possible links between a large number of its parts influenced the choice of the text used for this experiment. It was also desirable that the text be different from those used in the initial study from which the links were derived (described in chapter 4) so that if it were demonstrated that the link types provided any expectation, it could be shown that this was not dependent on the text used. The text used was a short text describing how to repair a bicycle puncture (reproduced in Appendix 1.3), and is described below in the 'Materials' section.

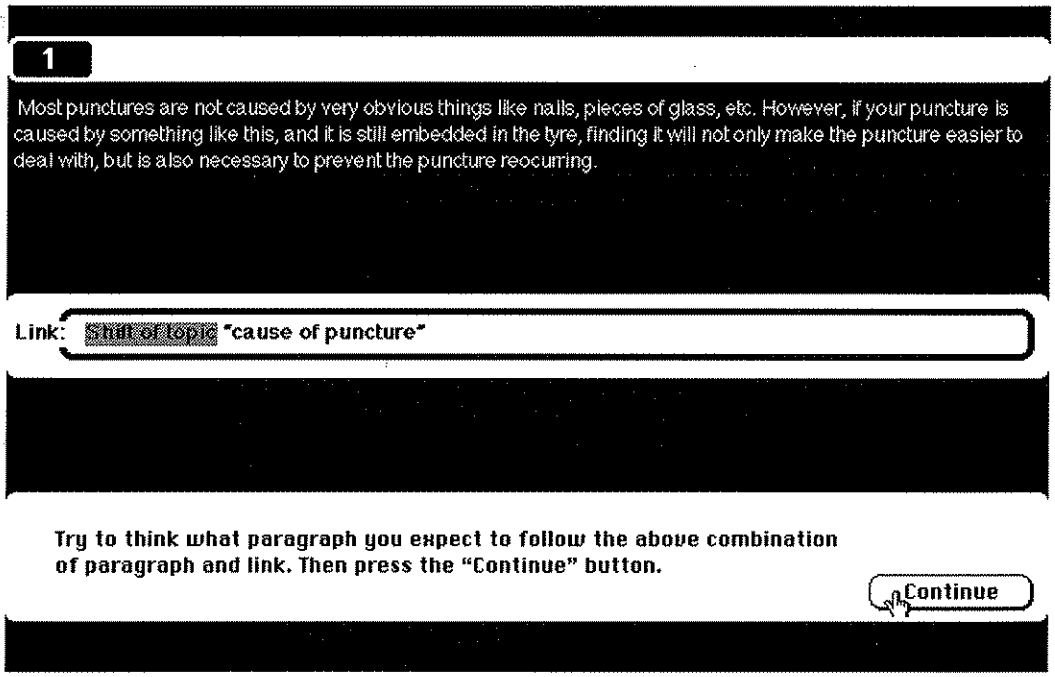


Figure 21: This shows a prompt paragraph, a link, and the instruction to the subject to think about what might follow these.

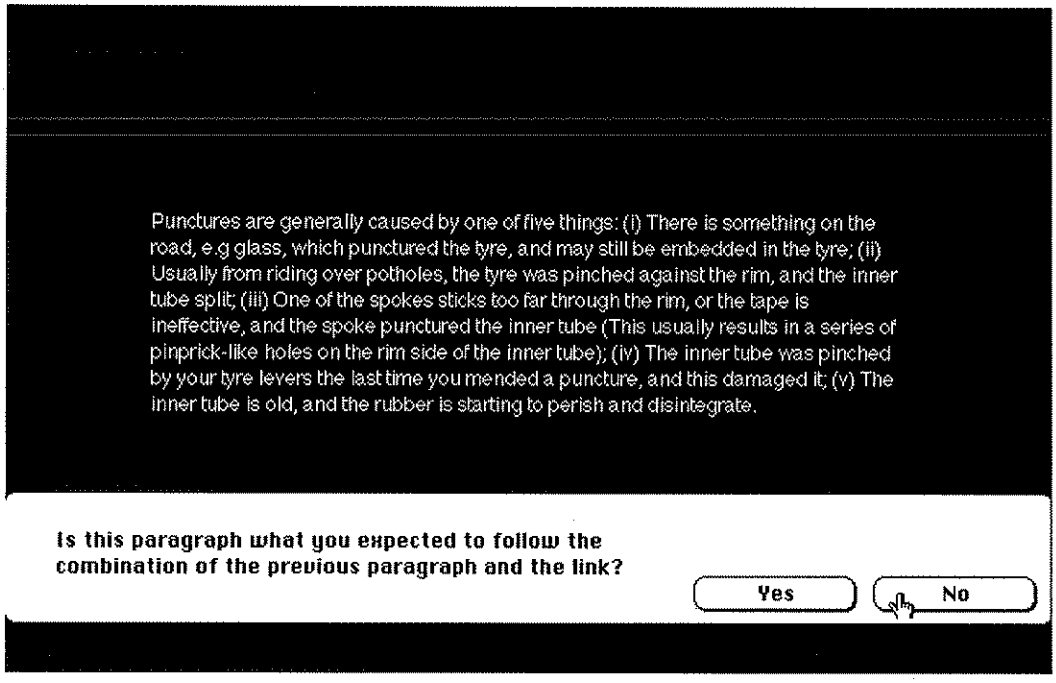


Figure 22: This shows a paragraph that might be shown after the prompt paragraph, and the question, asking the subject whether this is what was expected.

Results obtained by this method would be influenced by the degree to which the paragraphs were likely to be linked to the prompt paragraph irrespective of the relationship type. That is, this would influence a subject's claim that two paragraphs were or were not connected with a relationship type. This necessitates including in the experiment a control condition in which subjects are asked which paragraph is most likely to be linked without showing them a link type. Then, should the prompting with a certain link type consistently manage to increase expectation for an 'weakly linked' paragraph or reduce expectation for 'strongly linked' paragraphs, this would show the link-types' effectiveness at generating expectation.

So this implies the need for two treatments:

1. (Link) Ask subjects whether a paragraph is what they expected to follow the combination of the prompt paragraph and a given relationship type.
2. (Control) Ask subjects whether a paragraph is linked to the prompt paragraph.

The form of this experiment is to present the subjects in the 'Link' treatment alternately with a screen containing a prompt paragraph and a relationship type, and a screen containing one of a set of paragraphs. Subjects report on whether the paragraph following the prompt paragraph and the relationship type was what they

expected to follow it. For subjects in the 'Control' treatment, the experiment is identical except that they do not see the relationship type and they are asked to say if the two paragraphs are linked or not.

Ideally the set of paragraphs the subjects see would be such that it would be possible to rank them accurately in order of how appropriately they follow the prompt paragraph and the relationship type. The subjects' responses about expectation could then be compared with the prediction, and conclusions drawn as to how well the relationship types do in fact provide the correct expectation. These judgements about exactly which link should go where, and how suitable a certain link is in a certain place cannot be done however without a predictive methodology for authoring the links in hypertext which is outside the scope of this thesis. In addition, the argument for this method is circular, as an authoring methodology for these links would have to be based on detailed observations of what expectancy the links generated.

Therefore the experiment presented here is necessarily a preliminary experiment. As has been discussed (Chapter 4, section 2.6), the relationship types themselves are in a prototype form, so this experiment will not look at all the relationship types, or attempt to arrive at rules to describe how a particular relationship generates expectation, but will just attempt to investigate if any expectancy is generated when links are used.

For the experiment, it was necessary to have a set of paragraphs which could be linked with the prompt paragraph. In the absence of a predictive link authoring methodology, the selection of these paragraphs was made intuitively.

Subjects

26 of the 32 subjects who did Experiment 2.1 did the 'Link' treatment of this experiment (2 undergraduate and 17 postgraduate students and 5 staff from the Computer Science Department, and 2 others). For this treatment, familiarity with the relationship types was needed, which all these subjects would have had from the tasks in experiment 2.1 which asked them to form their own aliases of the relationship types and use the hypertext containing these.

Sixteen subjects were used in the 'Control' treatment of this experiment (10 postgraduate students and five staff from the Computer Science Department, and 1 other). In the 'Link' treatment 21 out of 26 (81%) and in the 'Control' treatment 14 out of 16 (88%) answered "Yes" to the question "Do you know how to repair a bicycle puncture?".

Procedure

Subjects in both conditions performed four trials of the experiment. For each trial in the 'Link' treatment they were presented a screen containing a paragraph (the 'prompt' paragraph) and a link type. Following each presentation of this screen, they were presented with a screen showing a different one of four target paragraphs and asked whether this paragraph was what they expected to follow the combination of the previous paragraph and the link type. They were then returned to the prompt screen. These two screens were seen in figs. 21 and 22. The prompt paragraph and the set of test paragraphs was different for each trial. The ordering of the trials was not changed, but in each trial the order of the test paragraphs was randomised.

The experiment was the same for subjects in the 'Control' treatment except that the link type was missing from the prompt screen and the question on the test screens was to ask them whether the two paragraphs were strongly linked.

Materials

A piece of text was needed for this experiment that fulfilled the following criteria:

- It should have a variety of links between its paragraphs so that these can be used by subjects in treatment 1 of this experiment.
- It should be reasonably short, not more than about 10 paragraphs and have some topic running consistently through the paragraphs. These would help the paragraphs to have links between them, and also to be related to each other irrespective of link type.
- It should be on a widely accessible topic.

A short text, describing in detail how to repair bicycle punctures was written for this (reproduced in Appendix 1.3), and four prompt paragraphs, links, and sets of test paragraphs were chosen. These are shown below in table 18. The numbers in the table refer to the numbered paragraphs of the text in appendix 1.3. It can be seen that the prompt and target paragraphs were different for each trial, so in the analyses which follow, we cannot compare paragraphs across the trials (paragraph 'A' in Trial 1 with paragraph 'A' in trial 2, for example).

	Trial 1	*Trial 2*	*Trial 3*	*Trial 4*
Prompt paragraph	**3**	**7**	**6**	**1**
Paragraph A	7	1	14	10
Paragraph B	6	8	7	11
Paragraph C	10	14	9	12
Paragraph D	11	9	2	4

Table 18: This table shows the prompt paragraphs and the sets of target paragraphs used in each of the four trials of Experiment 2.2. The numbers refer to the numbered paragraphs of the text in Appendix 1.3.

The four relationship types used for the links are shown below, with the text anchors which the links were attached to. The method of presentation of these links was seen in fig. 21, and the relationships' descriptions can be seen in full in chapter 4, section 2.6:

- Trial 1: Relationship 4 ("... small shift of topic ... different aspects of same subject...") was used. The text from the 'prompt' paragraph (Paragraph 3) that was linked was "cause of puncture".
- Trial 2: Relationship 12 ("One piece of text gives background information...") was used. The text from the 'prompt' paragraph (Paragraph 7) that was linked was "remove the wheel".
- Trial 3: Relationship 1 ("The two pieces of text ... are on the same topic...") was used. The text from the 'prompt' paragraph (Paragraph 6) that was linked was "tyre levers".
- Trial 4: Relationship 9 ("refinement ... specialisation...") was used. The text from the 'prompt' paragraph (Paragraph 1) that was linked was "Check the wheel for obvious causes of puncture".

2.3. Results

Each subjects' responses were collected and can be summarised as shown in table 19 and fig. 23. This shows, for each trial, two numbers associated with each paragraph (A, B, C or D) used in that trial. These are P_E, the percentage of subjects reporting that paragraph to be expected, and P_S, the percentage of subjects reporting that paragraph to be strongly linked to the prompt paragraph. These measures are frequency measures, describing the quantity of subjects who thought either (Treatment 1, the 'Link' treatment) that the paragraph in question was what they expected to follow a certain link or (Treatment 2, the 'Control' treatment) that the paragraph was strongly linked to the prompt paragraph. They are not measures of the extent to which a

subject's expectation was matched or the extent to which a paragraph was thought to be strongly linked.

Immediately, two things can be seen. The first is that in most cases the percentages add to more than 100, indicating that subjects reported more than one paragraph to be expected, or more than one paragraph to be strongly linked. The second is that, except for the third trial, the P_S scores are higher than the P_E scores.

	Trial 1		*Trial 2*		*Trial 3*		*Trial 4*	
	P_E	P_S	P_E	P_S	P_E	P_S	P_E	P_S
A	**27**	69	**38**	63	**35**	0	**77**	75
B	**65**	75	**69**	75	**38**	56	**77**	88
C	**15**	13	**27**	44	**27**	6.3	**35**	94
D	**27**	25	**23**	75	**15**	44	**15**	13

Table 19: This table shows, for each paragraph P_E, the percentage of subjects reporting that paragraph to be expected, and P_S, the percentage of subjects reporting that paragraph to be strongly linked to the prompt paragraph.

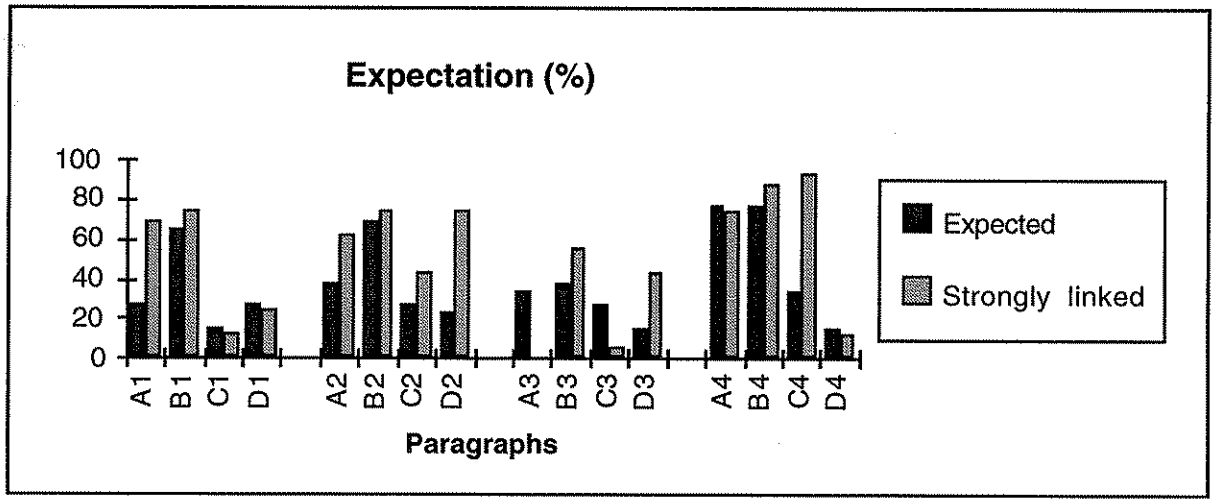


Figure 23: Chart showing, for each paragraph, percentages of subjects who responded positively to the 'expected' and 'strongly linked' questions.

For 38.2% of the times test paragraphs were presented, subjects reported that paragraph to be what they expected, whereas they reported them to be strongly linked 50.8% of the time. There is therefore a factor by which subjects are more likely to see two paragraphs as being linked than they are to see them as being linked by a certain relationship type. This is not surprising as it would be expected that the relationship types would be more discriminatory than just simple links. If the scores for 'strongly linked' in table 19 are scaled down by this factor (0.753, given by 38.2/50.8), then the chart in fig. 23 becomes that in fig. 24.

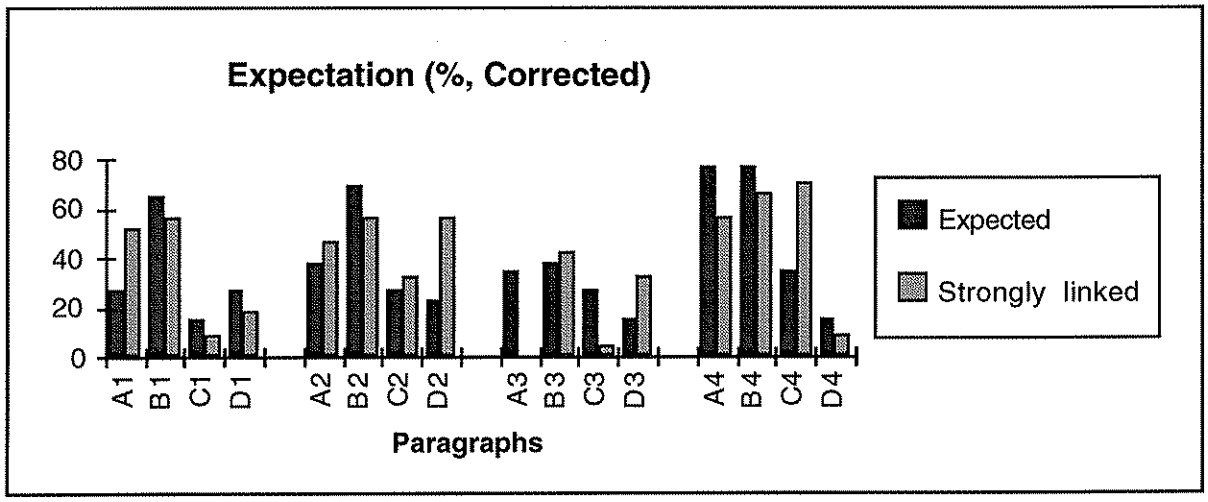


Figure 24: Chart showing, for each paragraph, percentages of subjects who responded positively to the 'expected' and 'strongly linked' questions.

Each of the trials in this chart will now be discussed individually. For each trial, below are shown the Tukey test results for firstly the 'Expectation' test, and secondly the 'Strongly linked' test. The mean of the responses for each of the four paragraphs in each Tukey test summary is shown. These correspond to the figures for the percentages in table 19, because a positive response (i.e. the subject selecting the paragraph as being linked) was coded as 1 and a negative response was coded as 0. The Tukey interval is then calculated and the "Conclusion" column records whether the null hypothesis (that the two means in question are not significantly different) is accepted or rejected.

Paragraphs Means (yn)	*Pairwise difference*	*yi-yj*	*Tukey Interval*	*Conclusion*
A 0.269	μA-μB	-0.385	(-0.719, -0.05)	Reject
B 0.654	μA-μC	0.115	(-0.219, 0.45)	Accept
C 0.154	μA-μD	0.	(-0.335, 0.335)	Accept
D 0.269	μB-μC	0.5	(0.165, 0.835)	Reject
	μB-μD	0.385	(0.05, 0.719)	Reject
$D\sqrt{MSE}$= 0.335	μC-μD	-0.115	(-0.45, 0.219)	Accept

Table 20: Tukey test results for 'Expectation' responses, trial 1 (α=0.05). The full Anova is in Appendix 7.8.

Paragraphs Means (yn)	*Pairwise difference*	*yi-yj*	*Tukey Interval*	*Conclusion*
A 0.688	μA-μB	-0.063	(-0.453, 0.328)	Accept
B 0.75	μA-μC	0.563	(0.172, 0.953)	Reject
C 0.125	μA-μD	0.438	(0.047, 0.828)	Reject
D 0.25	μB-μC	0.625	(0.234, 1.016)	Reject
	μB-μD	0.5	(0.109, 0.891)	Reject
$D\sqrt{MSE}$= 0.391	μC-μD	-0.125	(-0.516, 0.266)	Accept

Table 21: Tukey test results for 'Strongly linked' responses, trial 1 (α=0.05). The full Anova is in Appendix 7.9.

For trial 1, the Tukey tests (tables 20 and 21) can be summarised as $\overline{CDAB}$ for the 'expectation' response, and $\overline{CDAB}$ for the 'strongly linked' response. In conjunction with the charts in figs. 23 and 24, it can be seen that whereas subjects' expectation was largely restricted to paragraph B, both A and B were thought to be strongly linked. This suggests that the expectation provided by the link type in this trial is causing subjects to reject paragraph A, and this effect can be seen in figs. 23 and 24.

Paragraphs Means (yn)	*Pairwise difference*	*yi-yj*	*Tukey Interval*	*Conclusion*
A 0.385	μA-μB	-0.308	(-0.635, 0.02)	Accept
B 0.692	μA-μC	0.115	(-0.212, 0.443)	Accept
C 0.269	μA-μD	0.154	(-0.173, 0.481)	Accept
D 0.231	μB-μC	0.423	(0.096, 0.75)	Reject
	μB-μD	0.462	(0.134, 0.789)	Reject
$D\sqrt{MSE}$= 0.327	μC-μD	0.038	(-0.289, 0.366)	Accept

Table 22: Tukey test results for 'Expectation' responses, trial 2 (α=0.05). The full Anova is in Appendix 7.10.

Paragraphs Means (yn)	*Pairwise difference*	*yi-yj*	*Tukey Interval*	*Conclusion*
A 0.625	μA-μB	-0.125	(-0.531, 0.281)	Accept
B 0.75	μA-μC	0.188	(-0.218, 0.593)	Accept
C 0.438	μA-μD	-0.125	(-0.531, 0.281)	Accept
D 0.75	μB-μC	0.313	(-0.093, 0.718)	Accept
	μB-μD	0.	(-0.406, 0.406)	Accept
$D\sqrt{MSE}$= 0.406	μC-μD	-0.313	(-0.718, 0.093)	Accept

Table 23: Tukey test results for 'Strongly linked' responses, trial 2 (α=0.05). The full Anova is in Appendix 7.11.

The Tukey tests for trial 2 (tables 22 and 23) can be summarised as $\overline{DCAB}$ for the 'expectation' response. There was not a significant effect in the 'strongly linked'

response. This indicates that whereas there was no paragraph that a significant number of subjects thought was strongly linked, paragraphs A and B were significantly more likely to be reported to be what the subjects expected to follow the link type. There is also some discriminatory effect in these results; paragraph D was found to be, with paragraph B, most likely to be reported to be strongly linked and yet, as can be seen from the charts in figs. 23 and 24 and table 22 it was rarely reported to be likely to follow the link.

Paragraphs Means (yn)	*Pairwise difference*	*yi-yj*	*Tukey Interval*	*Conclusion*
A 0.346	μA-μB	-0.038	(-0.364, 0.287)	Accept
B 0.385	μA-μC	0.077	(-0.249, 0.403)	Accept
C 0.269	μA-μD	0.192	(-0.133, 0.518)	Accept
D 0.154	μB-μC	0.115	(-0.21, 0.441)	Accept
	μB-μD	0.231	(-0.095, 0.556)	Accept
$D\sqrt{MSE}$= 0.326	μC-μD	0.115	(-0.21, 0.441)	Accept

Table 24: Tukey test results for 'Expectation' responses, trial 3 (α=0.05). The full Anova is in Appendix 7.12.

Paragraphs Means (yn)	*Pairwise difference*	*yi-yj*	*Tukey Interval*	*Conclusion*
A 0.	μA-μB	-0.563	(-0.902, -0.223)	Reject
B 0.563	μA-μC	-0.063	(-0.402, 0.277)	Accept
C 0.063	μA-μD	-0.438	(-0.777, -0.098)	Reject
D 0.438	μB-μC	0.5	(0.161, 0.839)	Reject
	μB-μD	0.125	(-0.214, 0.464)	Accept
$D\sqrt{MSE}$= 0.339	μC-μD	-0.375	(-0.714, -0.036)	Reject

Table 25: Tukey test results for 'Strongly linked' responses, trial 3 (α=0.05). The full Anova is in Appendix 7.13.

The Tukey tests for trial 3 (tables 24 and 25) can be summarised as $\overline{\text{ACDB}}$ for the 'strongly linked' response. There was not a significant effect for the 'expectation' response. This is an unclear result; whereas paragraphs D and B were found to be significantly more likely to be reported to be strongly linked, there was no paragraph found to be significantly more likely to be expected to follow the link. This suggests that no paragraph was very strongly linked to the prompt by the relationship type. However, if the results for paragraph A are looked at, it can be seen that while no subjects reported paragraph A to be strongly linked, paragraph A had the highest number of positive 'Expectation' responses. Although this result is not significant, it

does suggest that the presence of the link is promoting expectation of a paragraph that might otherwise be unlikely to be considered to be linked to the prompt paragraph. The paragraphs can be examined in appendix 1.3. From table 18 it can be seen that for trial 3 the prompt paragraph was paragraph 6, paragraph A was paragraph 14, and the link type was "The two pieces of text ... are on the same topic ..." and referred to the text "tyre levers" from the prompt paragraph. Looking at these paragraphs, it can be seen that tyre levers are mentioned in the same context in both paragraphs (that is, that improper use of the tyre levers when repairing punctures can actually cause more punctures) which explains the high number of subjects reporting them to be linked on this topic. However, the paragraphs are very different otherwise, one listing causes of punctures, and the other explaining how to reassemble a bicycle wheel, which explains why they were not found to be strongly linked by any subjects.

Paragraphs Means (yn)	*Pairwise difference*	*yi-yj*	*Tukey Interval*	*Conclusion*
A 0.769	μA-μB	0.	(-0.31, 0.31)	Accept
B 0.769	μA-μC	0.423	(0.113, 0.733)	Reject
C 0.346	μA-μD	0.615	(0.305, 0.925)	Reject
D 0.154	μB-μC	0.423	(0.113, 0.733)	Reject
	μB-μD	0.615	(0.305, 0.925)	Reject
$D\sqrt{MSE}$= 0.31	μC-μD	0.192	(-0.118, 0.502)	Accept

Table 26: Tukey test results for 'Expectation' responses, trial 4 (α=0.05). The full Anova is in Appendix 7.14.

Paragraphs Means (yn)	*Pairwise difference*	*yi-yj*	*Tukey Interval*	*Conclusion*
A 0.75	μA-μB	-0.125	(-0.403, 0.153)	Accept
B 0.875	μA-μC	-0.188	(-0.465, 0.09)	Accept
C 0.938	μA-μD	0.625	(0.347, 0.903)	Reject
D 0.125	μB-μC	-0.063	(-0.34, 0.215)	Accept
	μB-μD	0.75	(0.472, 1.028)	Reject
$D\sqrt{MSE}$= 0.278	μC-μD	0.813	(0.535, 1.09)	Reject

Table 27: Tukey test results for 'Strongly linked' responses, trial 4 (α=0.05). The full Anova is in Appendix 7.15.

The Tukey tests for trial 4 (tables 26 and 27) can be summarised as $\overline{DCAB}$ for the 'expectation' response, and $D\overline{ABC}$ for the 'strongly linked' response. The most significant result here is that paragraph C, with the highest number of subjects considering it to be strongly linked, was thought to be what was expected to follow the link by only a few subjects. Less obvious is that paragraph A achieved relatively

few 'Strongly linked' responses but a relatively large number of 'Expectation' responses. This is seen most clearly in fig. 24, and suggests that the presence of the link type caused an increase in the proportion of subjects expecting that paragraph to follow the prompt paragraph.

2.4. Discussion

The results of the four trials can be summarised thus:

- Trial 1: The effect of the link type was to cause subjects to choose one paragraph as being linked significantly more than any other, and dissuade subjects from choosing what was otherwise found to be a strongly linked paragraph.
- Trial 2: Whereas no paragraph was found to be more strongly linked than the rest by a significant number of subjects, two paragraphs were found to be 'expected' by a significant number of subjects. Also, as in trial 1, subjects were dissuaded from choosing a paragraph found to be strongly linked.
- Trial 3: Although not significant, a large proportion of subjects reported a paragraph to be 'expected' which no subjects reported to be 'strongly linked'.
- Trial 4: As in trials 1 and 2, subjects in the 'expectation' treatment were dissuaded from choosing a paragraph that was found to be strongly linked, and there was a weaker effect of the frequency with which subjects chose a particular paragraph being higher in the 'expectancy' treatment than in the 'strongly linked' treatment.

From this it is evident that the main effect of the link types in the four trials was to reduce expectation for what might otherwise be 'strongly linked' paragraphs. A secondary effect was to increase expectation for weakly linked paragraphs. Had the results not been significant, they would have been inconclusive, or if the results for the 'expectation' condition had not been different from the 'strongly linked' condition, this would have shown that the link types were not producing any expectation.

The experiment was not designed to show any differences in effectiveness of the four link types used. It is interesting to see though that the most inclusive and thus perhaps the most ambiguous of the four (Relationship type 1 ("The two pieces of text ... are on the same topic ..."), used in trial 3) was the only one not to generate a significant difference in levels of expectation across the four target paragraphs. This suggests that it may be worse at generating expectation, but is not conclusive evidence as there were many other differences between the trials, such as the prompt and target paragraphs

used. It does suggest though that differences between the relationship types should be evaluated.

As was said before, this experiment is deficient in that only four of the relationship types were used in the test. However, the set of relationship types itself is not in its final form. Therefore until more work is done on the relationship types, they do not merit evaluating more than is necessary to demonstrate the principles on which they work.

This experiment has shown that the mechanism of expectation, discussed in chapter 3 can be used in hypertext links. Whereas the previous experiment showed that these links provide an advantage for users of hypertext, this experiment demonstrates that they can provide some expectation of what text they link to.

3. CONCLUSION

Previous chapters have focused on what characteristics a set of relationships ought to have and then on experimental work to derive a set of relationships with these characteristics. This chapter has taken this set of relationships and sought to test their usefulness in a hypertext setting and their method of operation.

The first experiment (Experiment 2.1) tested hypotheses relating to the use of the relationship types as links in a hypertext system. This showed that when the relationship names were attached to the links in a hypertext, subjects used these links in preference to others, and achieved greater improvements in scores when questioned on material from the hypertext system.

The second experiment (Experiment 2.2) examined that aspect of the relationship types which was designed to facilitate use of hypertext systems, namely their ability to promote expectation of linked information. This showed that the main effect of the expectation provided by the links was to reduce expectation for paragraphs poorly connected by the link types. This suggests that there was some consistent notion among the subjects of what should have been connected by the links used in the experiment. This effect would have benefits for the users of hypertext systems because it would not only allow them to follow the links they wanted, but also to discard links as being not useful to their goals without first having to follow these links to see where they lead.

In summary, these experiments (Experiments 1.1, 1.2, and 2.1) have shown that a set of relationship types can be derived which, when used as link types in a hypertext system cause an improvement in the users' performance. Furthermore these

relationship types were shown (in experiment 2.2) to give users some notion of what lay at the end of a link.

Although the experiments show that use of the link types is associated with an improvement in a hypertext system's usability, and that the link types generate some expectation, they do not demonstrate that this is bought about through alleviating the problems with hypertext discussed at the start of this chapter (those problems being cognitive overload and disorientation). The results as they stand demonstrate that the relationship types have some useful attributes when used as links in hypertext and merit further investigation. Aside from future work to extend the link types and to more carefully derive them, future empirical work will have to build on the feasibility study by taking an investigative approach to the link types. This would seek to establish the how and why the link types work, the precise nature of the benefit provided to the user, the relative effectiveness of the relationship types, their suitability for different tasks, and how they should be integrated with other hypertext tools.

Central to this work is the hypothesis that the link types allow users of hypertext some expectation of what nodes are connected to the node they are currently looking at. An experimental hypothesis that might come from this is that subjects using a hypertext system containing the link types would have a better grasp of the 'local' information space of the hypertext, but not necessarily a better grasp of the 'global' information than those subjects not using the link types. To test this, subjects might be asked to describe their notions of the 'local' and 'global' information spaces of the hypertext at various points in a hypertext system, or a method similar to that used by Gray (1990) for example might be used to elicit the subjects' models of the information space. This would provide descriptive data of what model of the information in the hypertext system the link types provide to the user, which would help to establish what assistance the link types provide.

Another area which needs to be looked at is how individual link types provide information to the user. This could be done with an experiment similar in set-up to experiment 2.2. For example subjects might be shown pieces of text with typed links leading away from them. Then these subjects would be asked what information they thought these links led to, either by having to describe it, or by being given a multiple-choice test. If carried out on an appropriate number of subjects, this would show (a) what the expected information was that each link provided, (b) how consistent this was between subjects, (c) how consistent this was between subjects using the information for different tasks, (if the experiment could be designed such that the

subjects had different motives for looking at the information) and (d) whether some link types promoted expectation of information more consistently than others. This data describing what various links made users expect could be used to create a description of the links from an authoring perspective, rather than a user perspective. Currently the link types' meanings are directed towards the user, but a parallel set of links could be created by asking what the relationship was between the information given to the subjects and what they reported as being at the end of the link (i.e. the information in (a), above). A set of relationships based on this would then allow authors of hypertext systems containing the links developed in this thesis to know what the relationship between two pieces of text should be for a certain link-type to be put in place joining them.

The outlines of future experiments given here show something of the work that could be done on these relationship types. They highlight and show methods of exploring issues that the experiments described here have not addressed, such as the relative effectiveness of the relationship types, their suitability for different tasks, and the nature of the added information that they give to the user.

This chapter has shown that the relationship types derived in the previous chapter, when used as link types in a hypertext system provide its users with some advantage. It has also shown that the mechanism by which they were designed to do this works and can be measured. The next chapter will discuss how the links could be used, and what implications they have for various areas of hypertext research.

It is plain that more work needs to go into both the derivation and evaluation of the links. Chapter 4 and this chapter have been primarily concerned with identifying the set of relationships, and evaluating them as a set of link types so as to test the hypotheses of this thesis. The work required before these relationship types could be used as a linking method in practice in a large, complex hypertext system will be examined in chapter 7.

6: Implications

"Reading online documents is like watching football
through a hole in a fence"(Dave Jones)

This chapter discusses the results of the experimental work and the ideas expressed in the preceding chapters. The implications of this work for the authors and users of hypertext systems, the systems themselves, and other computer-based information systems are dealt with. A discussion of future work, much of which continues themes dealt with here, is in the next chapter.

1. SUMMARY OF RESULTS

Below is a summary of the descriptions of relationship types that were eventually used as links. These arose from the experiments described in chapter 4, and the full descriptions of these relationships are given at the end of that chapter.

1. Refer to the same thing; on the same topic; mention the same thing; refer to the same general subject; common context.
2. Covered by the same general thing; subject overlap.
3. One paragraph describes something from the other.
4. Different aspects of the same subject; small shift of topic; topic remains the same, but is dealt with in a different context/ for different reasons/ in a different way.
5. Illustration or example.
6. Structure or intended function is the same.
7. Continue; sequence; narrative; a natural progression; a flow of time; directional; sequential; one precedes or succeeds the other.
8. Explains; answers "Why?" questions; elucidates.
9. Gives detail, refinement; more specific; specialisation; one is introductory, the other specialised.
10. Expand; elaborate; enlarge; amplify.
11. Contrast; compare; oppose.
12. Background information; general content.

Figure 25: Descriptions of the relationship types derived in chapter 4.

The process by which these links were derived also provided evidence that these link types appear to have meanings which are commonly and similarly understood across people and were present in both of the information domains from which they were derived. It was also demonstrated that they provided some usability advantage, and could be used to improve subjects' expectation of what text a certain piece of text was linked to.

These relationship types are still in a prototype form and need further development to widen the base of text and task types on which they are based. Similarly their evaluation, while it has shown their validity, needs to be extended. These issues will be dealt with in detail in the next chapter.

The other significant products of this thesis are the ideas set out in chapters 2 and 3 which gave rise to these relationships, and the implications these have for hypertext. These implications, and a discussion of future work are dealt with in this chapter and the next.

1.1. The relationship set as a component of hypertext

Relational links such as those described in this thesis can be seen as one of a number of ways of imposing structure and cues as to the whereabouts of information on an hypertext. This notion of hypertext components being seen as a range of tools available to do this was mentioned in chapters 2 and 3. The relational links developed here will now be compared with a range of these to examine their role and how they differ in what they provide for the user.

If hypertext with nothing more than nodes of text and simple, nameless links is taken as the 'base' form of hypertext then there are a number of extensions which produce a more structured hypertext system, or at least one in which the structure is more obvious. Examples of these are indexes, hierarchies, browsers, guided tours, and aggregates. They all in some way provide the user with information about the current node's relationship to the hypertext as a whole or to the nodes around it. They also are, as will be shown, each more or less appropriate for different information-gathering tasks in hypertext. What this section looks at is how the relational links, based on the results in chapters 4 and 5, compare with these other hypertext components, what features they have in common, and where they overlap with or complement each other.

Because of the great differences between hypertext systems, results obtained about the usefulness of different hypertext tools in different systems cannot be compared except to make general observations about what the tools are used for. There are though a

few studies in which different hypertext components are compared within the same hypertext environment.

Hierarchical organisations of the nodes in hypertext systems are frequently used, typically with either a graphical representation of the hierarchy available to the user or with each node containing links to allow the user to move up and down the hierarchy. There is evidence that for very 'directed' tasks they perform better than using only simple links. Mohageg (1992) compared linear links (allowing users to move only backwards and forwards through the text), a hierarchical organisation, simple links (where the placement of links was done based on keyword searches), and finally a combination of these simple links with a hierarchical structure. He set subjects simple factual questions about the information in a small hypertext system, and found that for this purpose, using hierarchical links, or a combination of these and simple links produced the best performance from his subjects (as measured by task completion times).

Gray (1990) too looked at hierarchical organisations of hypertext. She studied the mental models that people using hypertext systems built up, and found that the idea of a hierarchy was more readily comprehended than that of arbitrary point-to-point linkages. Most subjects who used a simple hypertext system came to understand the idea of the information being organised hierarchically, but very few understood that some links traversed branches in the hierarchy. She also looked at the understanding subjects got from using the hypertext system of how much of it they had covered. Subjects' estimates of the size of the (68-node) hypertext system which used only simple links and was hierarchically organised varied from 16 to 1000 nodes, with a mean of 219. These results suggest that although the idea of a hierarchy is acceptable, something more than links and a hierarchy is needed for the user to get an idea of the scope and size of the hypertext system.

Similarly to hierarchies, indexes seem to be suited to directed, fact-finding searches. In Marchionini and Shneiderman's (1988) study, 14 out of 16 subjects used an alphabetical index in Hyperties when asked to "perform efficiently in searching for specific factual information" but when the system was used as a public access system in a museum, more than two-thirds of all selections were made via links. However, in a different study Campagnoni and Ehrlich (1989) set factual questions to subjects who were using a computer-based hypertext help system. The subjects used an index only infrequently, despite the fact that the questions they were asked were largely worded so as to include index keywords. Instead subjects used a 'browsing' strategy using a combination of hierarchical and normal links. There was a difference between the

expert and novice users in their study though, with the expert users (i.e. those who were accustomed to searching for specific information) making more use of the indexes. They suggest that novice users may see indexes as a more 'expensive' strategy than browsing which, while it may take longer to find the correct answer, possibly imposes less mental load. This result reinforces the idea of using hypertext links to browse through a hypertext system being an 'easy' strategy for hypertext users, and this form of hypertext as a readily usable tool for information retrieval.

Indexes are compared with maps and guided tours in Hammond and Allinson's (1989) study. They looked at a hypertext system with simple links and compared subjects' performance using it with or without a map, an index, guided tours, or all three of these additional features. They also used two different tasks, exploratory (in which subjects were preparing for a multiple-choice test) and directed (in which the subjects had been given questions to answer). In all the conditions where additional features were provided, subjects covered more of the information in the hypertext system and, when asked to estimate how much of the hypertext they had covered, were more accurate. Where just the basic hypertext was provided, subjects thought they had covered the most material, but had in fact covered the least.

Where all three additional features were provided, how each of them were used was dependent on the task (the 'exploratory' and 'directed' tasks, described above) with guided tours more heavily used in the exploratory condition, and indexes being more heavily used in the directed condition. This provides more backing for indexes being useful for directed tasks, and suggests also that guided tours are useful for those users wanting an overview of the hypertext system (those users in the condition given only the guided tours as an additional feature covered the largest proportion of the hypertext and were almost exact in estimating how much of the hypertext system they had covered).

Maps and other forms of graphical representation of hypertext seem to support the user in knowing the scope of the hypertext system. They are sometimes provided as a means to give the user an explicit representation of the way the knowledge in the hypertext is organised to help the user to learn that representation, but there is evidence that they cannot easily be used in this role. Jonassen (1993) used techniques for mapping the organisation of ideas in an expert's knowledge structure and then structuring a hypertext system according to that same structure. The question they were addressing was whether the semantic information illustrated in graphical browsers would map onto the user's knowledge structure, so that the user replicated that structure in their own knowledge representations. Providing an explicit map

however had very little effect on subjects' structural knowledge except when the subjects were told that they would have to reproduce a map of the structure of the hypertext later. Subjects were also not able to guess what the relationship between pairs of nodes was when this information was hidden. He concludes that "merely providing structural cues in the user interface of a hypertext will not result in significant increases in structural knowledge acquisition". Novice subjects reacted negatively to hypertext systems (like the one which included the graphical browser) which were novel in appearance. From these results, Jonassen questions the suitability of hypertext for use in learning systems. It may be though that the subjects found the hypertext system's structure unhelpful and difficult to acquire because it was a representation of an expert's knowledge structure and was difficult for them, as novices, to comprehend.

Thus, there are differences in the tasks that different tools best support, with hierarchical structures and indexes being good for 'directed' tasks, and guided tours, maps and simple links being better for 'exploratory' tasks. For the user to form an appreciation of the scope of the whole hypertext system and the amount of it that has been covered, guided tours, indexes and maps are good, simple or hierarchical links less so. Finally, hierarchical structures or simple links, with their uncomplicated interface and functionality support novice use of hypertext systems better than indexes.

Relational links have some features that overlap with, and others which are complementary to these tools. Firstly they subsume the functionality of simple links and it might be expected that they would be found to be easy to use, useful for exploratory or 'browsing' tasks, but not able to provide users with a view of the extent of the hypertext system or an idea of how much had been covered. They might be best used in conjunction with indexes for example, although this would have to be tested. Where they provide functionality extra to that of simple links is in providing information about, and expectation of, what information can be found close to the 'current' node. In this respect they are providing complementary information to that given by indexes, guided tours and maps about the large-scale extent of the hypertext system by showing what is available at the local level.

When considering any new hypertext component, the cost of authoring it must be considered. This will determine whether it is possible to use it on a large scale and how well it compares with the authoring costs of other hypertext components. The authoring costs of links have already been discussed in chapter 2. There are important differences when comparing the authoring of links with the authoring of some of the

other means of structuring hypertext that have been looked at here. Firstly links are, by their nature, distributed throughout the hypertext system, so to author them attention must be paid to every part of the system (unless the links are generated automatically, as in Mohageg's study, above). Secondly, the nodes that a user finds as a result of following a relational link are frequently a step on a route to some information the user wants, rather than the information itself (as might be the case if the node was accessed by a link from an index). Therefore it is vital that the user finds appropriate follow-on links from that node. So, throughout the hypertext system it is much more important for relational links to be consistently authored than it is for index links, for example.

Tools in hypertext are not general-purpose, but rather can be used in one part of the hypertext system and not others, or are carefully tailored for each point in the hypertext system where they might be used, and are explicitly presented for use only at those points (For example, a link which claims to elaborate on topic X is a highly specific tool which can only be used in the hypertext where topic X is mentioned). Because of this and because of the size a hypertext system can reach, authoring a hypertext system such that it contains tools of moderate complexity (e.g. links, indexes, guided tours, etc.) can be an arduous task and a number of approaches for automatically generating usable hypertext tools have been tried. Guided tours for example, in their traditional form require a lot of authoring effort. The author must decide on the purpose of a particular guided tour, make sure they know about all the relevant nodes and that they are included in the tour in a sensible order. A automated approach to guided tour authoring is given by Smeaton (1992). He describes a way in which guided tours could be automatically generated from a user's query using an algorithm which determines which nodes make up the tour on the basis of the occurrence of words from the user's query in the nodes' text. He gives no data on the effectiveness of these automatically generated tours, but aside from the problems for the user in choosing appropriate access terms (cf. the 'Vocabulary problem' discussed in chapter 4) and not knowing whether all the relevant information has been included in any particular tour, it is plain that such tours can never be as complex or inclusive as manually authored tours where the author can add to the tour by careful ordering of the nodes visited and inclusion of extra nodes or omission of nodes with irrelevant or duplicate information.

Another automated method, that of 'aggregates' is put forward by Botafogo and Shneiderman (1991). By analysing the structure of hypertext system, how clustered and tightly linked parts of the system were, method was able to identify groups of

nodes that were highly related semantically. They suggest that these nodes could be aggregated to form a more abstract kind of node. This method of course relies on the hypertext system being carefully authored to start with, with the likelihood of any two pieces of information having a link between them being proportional to their semantic relatedness. They do not report any evaluation of this method, but in many respects aggregates are like hierarchies.

Ways have been tried of generating maps (as in Collier's (1987) Thoth-II) and links (as in Mohageg's (1992) study, above). These methods produce tools which are not as useful as those built 'by hand'; the map in Thoth-II was found to be overcomplicated and rapidly grew too large to use (Utting and Yankelovich, 1989), and the links generated on the basis of keyword searches used by Mohageg were found to be relatively ineffective when compared with (manually authored) hierarchical links. Lacking a means of modelling either the information in a hypertext system or users' tasks, components of hypertext that are created automatically appear to be simplistic and unable to meet the users' needs.

Partly due to the large amount of variability between different forms of the same hypertext component it is difficult to compare their authoring costs. It is undoubtedly the case though that authoring relational links of the type developed in this thesis must incur a high authoring cost relative to other hypertext components. Like authoring guided tours, authoring relational links necessitates examining many nodes in the hypertext. It then also involves assessing what the relationships between nodes are, and checking that nothing that should be linked has been ignored. Section 6 of this chapter examines how authoring these links will be different from authoring other types of links, and argues that because they consist of a finite set of types, will be easier than authoring relational links with meanings created on an *ad hoc* basis.

2. ASSESSMENT OF RESULTS

Because this work seeks to be a demonstration of feasibility, rather than a proof of a theory about the nature of hypertext links, the question arises of how much can be drawn from the results. Thus, the results might show the feasibility of using relationships which promote user expectation in hypertext. However, it does not automatically follow that this conclusion holds for all hypertext usage. Differences in the text types used in the hypertext, the user's task and the range and combination of other hypertext tools available to the user may all influence the usefulness of the relationship types established in this thesis.

This issue of the generality of the results are can be divided into two parts. First, how generally applicable are the relationship types on the basis of the derivation work and second, how generally applicable are the results of the evaluation of these relationships? These questions are addressed below.

2.1. Generality of the derivation process

Of the two areas in which the issue of generality will be discussed, this is the more important. Suppose the evaluation showed the relationship types to be useful, but their derivation was such that they could have only narrow areas of application. Then despite the evaluation work, the predictions that could be made of the usefulness of the relationship types would be limited, and to produce more generally applicable relationship types, a further cycle of derivation and evaluation would have to be done. However, if the derivation work showed that the relationship types were, for example, applicable to a broad range of text and task types, then evaluation work of comparatively narrow scope, while it would not provide definite answers about the general-purpose use of the relationships, if it were successful, would suggest that similar success might be found over a wider scope and that further evaluation of the same relationship types was justified.

The relationships are of course limited in many ways; for example the specification of a 'relationship' assumes that users of hypertext want some expectation of what lies at the other end of a link and limits the purposes for which the link can be used. For example, because just the associations between pieces of information are stressed, the relationship types would be unsuitable for tasks such as looking up a word in a dictionary or a subject in an encyclopaedia, where a text-searching method would be more appropriate.

The principal aspects of the derivation work that affect the generality are the type and number of texts used from which the relationship types were derived. As was said at the beginning of chapter 4, there is no clear feature that makes the texts used in hypertext systems different from other texts but they do share some broad features, such as typically being explanatory, didactic or descriptive texts. Such texts were used for the derivation experiments. So, if it is assumed that hypertext systems predominately use texts of this type then some degree of generality can be claimed for using the relationship types derived in chapter 4 in other texts used in hypertext systems. This generality is both for the meanings of the individual relationship types and for the range of relationship types. A text type to which this set of relationship

types is not generally applicable may contain relationships outside the scope of the set, or may cause the relationships to be interpreted in different way.

The relationship types were derived from observations of relationships in two texts. Relationships were seen in both these texts which then went on to form (in experiment 2.2) a single relationship type in the final set of relationship types. This agreement in the range of relationship types seen in the two texts suggests that there is evidence for some 'universality' for this set. This view is reinforced by the consistency with which the different subjects in experiment 2.2 created categories out of similar sets of relationship descriptions and then assigned to them similar meanings.

Therefore it is likely that further derivation of link types will refine these link-types' meaning and add only a few 'new' link types, rather than resulting in a new set for every pair of texts from which the relationships are derived. So although it cannot be said that the set is completely 'general-purpose' (and indeed, it would be impossible to ever prove this) there is evidence for it being applicable to a range of text types and information domains.

2.2. Generality of the evaluation process

While the relationship types were shown to have usability benefits for users of the hypertext system described in chapter 5, this hypertext system and the tasks the users were asked to perform using it represent only a small part of the ranges of the possible forms of hypertext and tasks hypertext systems are used to support. There are two main areas in which the of the evaluation process could be questioned. These are the construction of the hypertext system that was used for the evaluation, and the tasks that subjects were asked to perform.

Looking briefly at the first of these, it is obvious that there is a great deal of variability between hypertext systems. Some of these differences, in particular the range of choice of hypertext components and the variations in functionality of individual hypertext components, were expressed in chapter 2. Different hypertext systems present information in different ways, and give users different combinations of tools to control the presentation of information and navigate around the hypertext. It is likely that the combination of tools available in hypertext affects the usability and usefulness of any individual tool (For example, Hammond and Allinson (1989) found that where subjects used a hypertext system with links and one additional tool, either a map, an index or guided tours, the relative usages of the two tools varied considerably depending on what the additional tools was). This presents a problem for the testing of any new tool; on the one hand, if it is to be tested as part of a usable hypertext

system the system must be made as realistic as possible and the interaction with other tools must be considered. On the other hand, practically, it would be impossible to take every relevant variation of hypertext design into account, and in experimental work to evaluate such a tool (such as here, the set of relationship types), care must be taken not to add complexities beyond what is necessary.

In both the design of the hypertext system for the previous chapter's evaluation work and in the choice of the tasks which the experimental subjects were asked, the selection was made so that these were typical rather than specific. That is, the features of the experimental hypertext system were chosen so that the relational links could be tested in an environment typical of hypertext systems as a whole (for example, one which included a simple hierarchical structure, and simple navigational links) rather than attempting to test them in a controlled range of hypertext environments, in the presence or absence of various hypertext components. Similarly a large range of task types were not examined, the purpose of which would have been to enable a comparison of the efficacy of the relational link types in different task conditions. Rather, a typical task was used, the asking of simple questions about the content of the hypertext system which required information from various points in the hypertext. Both of these courses of action, looking for the general, typical hypertext design and task condition, reflect the work's status as a feasibility demonstration.

Looking more closely at the question of what task the subjects should have been set in the experimental work, this and indeed the question of what tasks a hypertext system should support is hard to answer. Several authors divide user behaviour into 'exploratory' and 'directed' (Hammond and Allinson, 1989), or 'browsing' and 'analytical' strategies (Campagnoni and Ehrlich, 1989), or 'browsing' and 'searching' (Marchionini and Shneiderman, 1988). In each of these cases the distinction between the two is the same; the names 'browsing' and 'searching' will be used here. These forms of behaviour do not necessarily map directly on to tasks but browsing is usually associated with looking for general information or with looking to see what is available, whereas searching is associated with looking for specific pieces of information. For example in Hammond and Allinson's (1989) experiment, subjects were either preparing for a subsequent multiple choice test (and 'browsed'), or had been given a series of questions to answer (and 'searched' for this specific information).

In hindsight it can be seen that the tasks used in the experimental work were 'searching' tasks with the subjects looking, while not always for specific facts, at least for the answers to set questions. While a feasibility study should not be

overcomplicated, it would have made the results of the feasibility study more generally applicable if these two extremes of task type had been used, and perhaps the feasibility study ought to be extended to include a simple 'browsing' task before any other future work is done. The discussion of hypertext components in the previous section contained evidence that suggests that links are more suited to 'browsing' tasks than they are to 'searching' tasks, so an evaluation using a 'browsing' task is likely to be at least as demonstrative of the link types' usefulness as the evaluation work done here.

The results of the experimental work in chapter 5, although they showed the benefits of using the relational link types in hypertext were not as strong or as conclusive as they might have been, and this provides another area in which the generality of the results might be questioned.

However, where the results were weak or were not shown to be significant, they still exhibit trends that are in agreement with what was hypothesised. For example, in experiment 2.1 in chapter 5, subjects using a hypertext system were either shown the link type labels or had the link types differentiated by colour, or were shown neither or both of these cues. It was found that the colour cue interfered with subjects' performance, and only those subjects who were shown just the link type labels used a significantly greater number of relational links and answered the questions significantly more accurately than subjects in other treatments. The treatment in which subjects were shown the link type labels and the colour cues was still better (but not significantly so) on these tests than the treatments which were not shown the link type labels at all, indicating that the effect of the link types was beneficial but slight, rather than contrary.

Two things can be said in support of the results obtained. First the statistical tests on the results are conservative and test for predicted effects. So it can reasonably be said that the results although not dramatic, are valid where they are shown to be significant. Second, as has been noted in the previous two chapters, at points throughout the derivation and evaluation work things were done which, while suitable for the derivation and evaluation of an experimental set of relational types for a feasibility study, could have been done more rigorously. The effect of these shortcomings (of the derivation process, the experimental design, the application of the link types to the experimental hypertext, etc.) will tend to be to reduce rather than increase the effectiveness and usability of the link types. For example, if the relationship types had been derived from more texts, or the categorisation process had been carried out by more subjects, it is likely that the relationship types' meaning

would have been made clearer. This may then have made the relationships' effectiveness at generating expectation in the hypertext system greater (and would certainly not have lessened it). Again, in the evaluation of the link types, if the experimental hypertext had been created with greater care and with more attention paid to the placement of the correct relationship type on each hypertext link then it is likely that the difference in usability between the simple, unlabelled links and the typed links would have been greater.

3. COMPARISON WITH OTHER APPROACHES

In chapter 3 some sets of general-purpose relationships were examined. They will now be compared with the set of relationships developed in this thesis. Table 1 and table 4, both in chapter 3, show respectively the relationships used in RST (Rhetorical Structure Theory, Mann & Thompson, 1988), and in Textnet (Trigg and Weiser, 1986). The set of links derived in this thesis and summarised in fig. 25 above will be compared to each of these.

Firstly, the set of RST relations contains some which are very similar in name to the set given here. For example "Elaboration", "Background", "Sequence" and "Contrast" from the set of RST relations in table 1 (chapter 3) correspond to similarly named relations among those proposed in this thesis (fig. 25). Likewise, the set of 'Normal' links used in Textnet also contains some similar link types, for example "Background", "Generalisation/ Specification", "Summarisation/ Detail", "Alternate-view", "Explanation" and "Continuation" may also correspond to relations in fig. 25. The remainder of the relationship types in fig. 25 differ from those used in Textnet and RST, by being different in meaning or in that they make the meanings of links more or less inclusive.

The chief differences in these sets of relationships arises from the different purposes for which they were developed. RST relationships were developed to provide formal descriptions of texts and so include such links as "Evidence", "Volitional cause", "Antithesis" and "Condition" These show how pieces of text are related from the point of view of looking at what the pieces of text do, what function they perform with respect to each other. On the other hand the purpose of the relationships identified in the empirical studies of this thesis is to allow their users to anticipate what text they link, and they reflect this purpose by providing information on how another piece of text can be understood with the knowledge of the text the user (of the hypertext system) already knows.

Similarly the Textnet relations (table 4, in chapter 3) differ from those identified in this thesis because their primary role is to allow users to comment on or to annotate pieces of text. For example, Textnet relations consist mostly of 'commentary' relations, allowing their user to put forward some view about a piece of text. Of the remainder, only a few have a role similar to those relationships developed in this thesis. For example Textnet's "Generalisation/ Specification" link may play a similar role to the "Covered by the same general thing..." and "Gives detail, refinement..." relations (see fig. 25).

The similarities between these three ways of describing relationships in texts lends support for there being some 'universal' relationship types. The relationship types given in this thesis have a number of significant advantages for the purposes of hypertext navigation:

- The relationship types used in Textnet and RST were compiled from sets of relationship types in other works and cannot therefore be said to be complete sets, describing all the relationship types that can be seen in a text. The relationship types described here however, because they were empirically derived from studies of relationship types seen in some texts can at least be said to be complete for those texts. Moreover, extending the process by which these relationship types were derived so that they become based on a greater variety of texts would bring them closer to being complete and make them more widely applicable.
- Unlike those links in Textnet and RST, the links described here were derived specifically for the purpose of hypertext navigation (whereas RST relationships, for example, were intended to be an analytical tool for describing texts).
- The links given here are based on verbose descriptions rather than being single word names. Their meanings are therefore less open to misinterpretation, and may be more accurately defined.
- Because these links were derived empirically, and the method for deriving them is well documented it is relatively easy to improve them, by basing them on a greater variety of texts or task types, by different methods of statistical analysis, or by altering or widening the scope of any aspect of their derivation.

4. HYPERTEXT SYSTEMS

4.1. Usage of the links in hypertext systems

There exists wide scope for use of links such as those proposed in this thesis in hypertext systems. More empirical work still needs to be done, but examples will be outlined here to illustrate the usefulness of these relationships in hypertext linking.

Using the numbers in the list of relationships (fig. 25, above), relationship 7 ("Continue, sequence, narrative...") is the most obvious, as this is already used in an implicit form in the majority of existing hypertexts to go from one node to another that directly follows on from it. Similarly, versions of relationship 1 ("Refers to the same thing...") are seen in existing hypertexts, where two nodes that deal with the same topic are linked. A link of type 2 ("...same general thing...") might join two nodes, both of which could then be connected to another node by a link of type 12 ("Background information").

Naturally there is scope for using two or more of these relationships between two nodes. So, for example, a hypertext node which mentioned "Current problems in hypertext usage" might have a type 4 ("Shift of topic") link to "Problems in hypertext navigation" and a type 5 ("Illustration or example") link to some practical example of a problem with hypertext usage.

The links' placement in the hypertext system could be affected by such factors as:

- The user group for whom the hypertext system was intended. For example an 'expert' group might not need the benefit of links explaining topics that would be essential for a 'novice' group.
- The ways in which they are presented to the user in a hypertext system. If screen space was limited, for example, the number of links that could be fitted on one node might be limited.

The examples above only show how the link types put forward here might be used and do not necessarily show them being used in the most appropriate way. There is still much work that needs to be done to determine guidelines for the placement of these link types within a text. The examples though do show something of the way in which the links can connect two pieces of text independently of their subject area.

4.2. Semantic and physical consistency

Currently there are almost as many ways of implementing linking structures in hypertext as there are hypertext systems. The central idea of this work is the idea of a fixed set of relationships, equally applicable to any information domain. If such a set

of relationships was used for linking in hypertext, this would bring some consistency between the linking semantics of different hypertext systems.

There might still be differences between the other features of hypertext systems, such as node sizes, screen presentation, and between the other navigation tools provided, such as maps and hierarchical or derived links. However, because it is the links between nodes that represent the large-scale semantics of a hypertext system, they have an importance greater than any other component of such a system. Because of this key role played by links, the consistency bought about by the use of general-purpose link types might promote consistency among other areas of hypertext. For example the link types' semantics would, because of the nature of the individual relationships in the set used, determine what information was put in a particular node, how a piece of text was divided between nodes, and because of the range of link types available, what nodes might be made available from any given node.

Then it is possible that common functionality of tools between hypertext systems might allow some commonality in their interfaces. Waterworth and Chignell (1989) argue that the complex interrelationships of tools in hypertext and the difficulty in finding any unifying concepts make hypermedia systems a challenge for interface designers. A set of relationships such as that proposed in this thesis has the potential to alleviate this by formalising the tools and allowing the same tools to be used in the same way across hypertext systems. Then, in the same way that in other areas of user interface design, conventions for the appearances and behaviours of similar things have arisen, conventions may also arise that determine the presentation of links.

4.3. Methods for describing hypertext

Descriptions of hypertext systems, at any level more abstract than that of screen objects currently fall into one of two kinds. Either they are those of hypertext mark-up languages and other tools for text-to-hypertext conversion, or they are the internal representation of hypertext systems and used for indexing and searching information held in the hypertext. It is possible to envisage a fuller description, which might include some representation of what information is held in the hypertext and how that information is dealt with in the hypertext. A set of descriptive link types is a step towards building a description of interrelationships within a hypertext. It must be a set, rather than link types created in an *ad hoc* manner, so as to be (i) predefined and finite - so that the tools that use the link types can be built in advance and can be complex, and (ii) richly defined and accurate - so that the meaning of each link-type is

well known. Then, this set of link types must be general-purpose to enable any method of description of hypertext to be generalised over many hypertext systems.

Means to describe hypertext systems such that something of the meanings of the interrelationships in the system are captured could provide significant benefits even if no attempt was made to provide any 'understanding' of the content of the hypertext. For example, searching methods could be made more powerful. Rather than just searching for text fragments, the types of links attached to these could also be specified. The user might search for the word "hypertext" with "Explains" or "Elaborates" links attached.

Another example of how a description of hypertext might be used is in looking at whole hypertext systems. The prevalence and patterns of placement of hypertext links could be summarised to provide information about the hypertext as a whole. So, a hypertext system that had a prevalence of a certain link type might denote a certain style of hypertext, much as we can perceive the difference between text types (e.g. textbooks have a more 'explanatory' style than reference books).

4.4. Text-to-hypertext conversion

Any general-purpose hypertext component, whatever it is, presents an obvious benefit for text-to-hypertext conversion. That is, because it is general-purpose, any rules or methods developed for applying it to a piece of text and using it as a building-block of a hypertext system can be reused.

Text-to-hypertext conversion using the set of relationship types described in this thesis as links will require more effort than putting simple unnamed links into the text (as is the case with much hypertext authoring). It has been shown however that this set of link types provides a usability advantage over simple links. Moreover, the effort required to author a hypertext with this set of link types could be lessened by developing authoring tools (see section 5 below), and will probably be less than is required to author a hypertext system with 'complex' links, where each link is individually named and placed.

4.5. Merging hypertext systems

As was said above, a common set of link types for use in hypertext systems is a step towards a language of description for hypertext. If some aspects of the semantics and structure of a hypertext system could be examined through the use of a description of hypertext, then it may be possible for common features between hypertext systems to be found. This would then allow two or more hypertext systems to be merged, or alternatively, for the user to be able to travel from one hypertext system to another

without being aware of doing so. Distinctions between one hypertext system and another would become blurred, and this would come close to Bush's (1945) 'Memex' or Wells' (1938) idea of the 'World Encyclopaedia', all human knowledge available through a single hypertext-like structure.

5. USER CONSIDERATIONS

5.1. Navigation

One of the characteristics of the 'disorientation' problems discussed in section 6.3 of chapter 2 is that users of hypertext systems do not know what is immediately available from the hypertext. It was shown in the previous chapter that the links proposed in this thesis facilitate users' expectation of the text at the end of a link. This suggests that these links should alleviate some of these problems by increasing expectation of what text is linked to the current node in the hypertext.

5.2. Familiarity and learning

There are two sorts of learning that need to be addressed, the users' goal of using the hypertext system for learning some knowledge contained within the hypertext, and the necessity of learning about how to use the hypertext system.

Looking at the first of these, Zhao (1994) examined the effect of relational link types on learning knowledge from hypertext systems. He tested subjects on their ability to retrieve information from an experimental hypertext system, while manipulating whether the names of the link types used were visible (As with the experiments in chapter 5, in the case where the link types were not visible, the links were still usable). The set of link types he used showed relationships between nodes but he made no claims for this set of link types' usefulness or generality. He found that where the link types' names were visible, scores were significantly better, and concludes that "explicitly labelling links with semantic relations has a positive influence on goal-oriented learning".

There is evidence from his study that this effect is due not only to navigation benefits (i.e. with the labelled links the subjects knew where to look for things) but also because the cognitive load of the subjects was lessened. A possible explanation for this decrease of the subjects' cognitive load comes from Experiment 2.2 (chapter 5) in which it was found that the link types identified in this thesis promoted expectancy of some paragraphs and decreased expectancy of others. Similarly, the links in Zhao's experiment could have been allowing subjects to discard some links immediately as being obviously irrelevant to their goals, which would reduced their cognitive load.

The second form of learning that may be affected by the link types proposed in this thesis is the learning about how to use the hypertext system that a user must go through. With respect to this, the benefit to the users of these relationship types is that having become familiar with them in one application, they will be able to approach another application already knowing something of how to navigate around it. This may make the initial stage of learning how to use a hypertext system less of an obstacle.

6. AUTHORING CONSIDERATIONS

This section looks at what the impact of the link types proposed here might be on the authoring process. This section argues that the authoring would be made easier and then that the quality of the resulting hypertext systems would be improved.

The main points made by this section are these: Firstly, through constantly using the same set of relationships irrespective of the hypertext system being created, authors may become practised at authoring, leading to time savings. Secondly, because the set of relationships is 'general-purpose' it will be worthwhile developing more powerful authoring tools and methodologies which will in turn improve the quality and efficiency of authoring. Thirdly, using a well-defined set of relationships will enable authoring of a hypertext by multiple authors while still allowing the use of consistent, complex links.

6.1. Efficiency

One of the dimensions of hypertext (from Halasz, 1988) discussed in chapter 2 was that which described a hypertext system as being a 'browsing' or 'authoring' hypertext, that is whether it had been carefully 'hand-built' at great cost, to provide much navigation information to the user, or whether it had been built quickly and cheaply with a simple, perhaps mechanical, authoring process but posing navigation problems for the user due to the simplicity of its links.

The set of link types identified in this thesis may do something to bring the two ends of this dimension closer. Because the set is predefined and can be used in hypertext systems covering any information domain, it is worth developing guidelines and methodologies to govern the links' placement in a hypertext system. If these are developed, then authoring a hypertext system using these links is likely to be easier than building a hypertext where each link is specially created and placed (the 'browsing' end of the dimension discussed above). They will also provide more information than the simple links that exist in hypertext systems at the 'authoring' end of the dimension.

6.2. Maintenance

Brown (1988) suggests that the largest cost of authoring a hypertext system will be that of maintenance. A simple reason for this is that current hypertext systems, necessarily written by inexperienced authors, are likely to require substantial changes. This maintenance cost can be inferred not only from our experience with writing programs, but also because the abstractions we use for hypertext are low-level and will thus require, like assembly-language programs, much effort to change. Also hypertext systems built with 'simple' links will demand more analysis of the hypertext from those who will later maintain it, because it is likely that the use of simple, nameless links causes some of the meaning originally intended by the hypertext system's author to be lost. Collier (1987) says, "Every [hypertext] link has a reason, which should be recorded by the author"; there is information present in the authoring process, which is lost because of the lack of expressiveness of hypertext tools and structures. It is in this area of documentation of the hypertext system that the link types proposed here may act as an aid to maintenance. If, simply by showing the meaning of the relationship between the two nodes that they link these link types are able to capture more of the intentions of the hypertext system's author, then the task of maintenance must be made easier. Furthermore, because it is a well-defined set of link types, independent of any individual hypertext system, using such a set of links encourages the development of some sort of underlying representation of the hypertext system. Then, one advantage of such a representation is that it would be easy to add any information necessary for future maintenance to it.

6.3. Group authoring

Rada (1991) argues that hypertexts will be of a higher quality when authored collaboratively. Authors' co-authors are their readers, and vice versa and there is a continual assessment and need for each author to understand the others' model of the hypertext. Therefore collaborative authoring encourages the author to develop a model of the hypertext from the reader's perspective.

The impact of the set of link types proposed in this thesis is that because they have been developed to be understandable consistently across people it allows group authoring to be carried out using meaningful link structures. In contrast, without a set of link types consistently understandable across a group of hypertext authors, they would be either forced to use simple links or there would be inconsistencies in the meanings of the same link when authored by different authors.

6.4. Consistency in authoring

'Consistency' here means not so much the consistency between the behaviour or components of hypertexts, that is, that they can be used in similar ways or that similar link types in separate hypertexts have similar meanings. Rather it means consistency between the construction of the hypertexts. For example if two authors were putting links in place in identical collections of nodes, consistency in their authoring would mean that they would put the same link types in the same places. Consistency in this respect would reinforce for the user the link types' meanings because their meanings are connected with the situations in which they are used.

Garzotto et al (1993) argue that the presence of a model to structure the authoring process of hypertext systems would improve the resulting systems by making them more consistent, in the manner described above: "It is clear that tools for specifying hypertext structures can help authors to avoid structural inconsistencies and mistakes, and that applications developed according to a model will result in very consistent and predictable representation structures. As a consequence, navigation environments will also be predictable, thereby helping readers to master complex documents and reducing the disorientation problem". The link types proposed here do not imply any such model or even a set of guidelines for their placement in a hypertext system. These link types however, because they form a general-purpose set lend themselves to being part of an authoring tool, for the same reasons that they could form some means of describing hypertext systems (Section 3.3, above). That is, because they are predefined, a finite set, and the meanings of the relationships they represent in hypertext systems are well-defined. Then, in an authoring tool, constraints and guidelines could be put on these link types' placement, which would help to make the authoring of the hypertext system consistent.

7. MULTIMEDIA CONSIDERATIONS

The work described in this thesis looks for a set of links that can be used between text chunks, and does not address the usage of links in media other than text. Currently hypermedia systems, that is systems that function like hypertext systems, but which contain information in media other than text, remain primarily text-centred. In such systems, the non-text information (e.g. diagrams, photographs, sounds, clips of video, etc.) tends to be linked to a single piece of text in order to express that single piece of text in a different way. For example, someone's name might be mentioned in a hypermedia system, with a link to a photograph of that person, in much the same way that figures or photographs in a book are referenced from the text of the book.

The difficulties present in any more complex linking lie in the lack of definition of non-text media. For example, if one takes the general area of black-and-white illustration, the relationship types needed for photographs, charts, maps, architectural drawings, graphs, and sketches may all be quite different.

Partly for this reason it is rare to find anything other than simple links from pieces of text to pieces of non-text information, and the linking together of pieces of non-text information seems not to have been addressed at all. There may however be some use for complex, meaningful links to non-text information, and even between non-text information. It does not follow that the link types used in this thesis between pieces of text will be usable for non-text information, but it would be an interesting extension of this work to look for such links in non-text media.

8. THE METHODOLOGY

An important aspect of this thesis is the methodology it provides for investigating hypertext links. As has been said, the link types developed in the empirical work are at present limited and not directly applicable to hypertext. They were derived from observations carried out in a limited quantity of text, on only two text types, and there are aspects of their derivation that could be improved.

The methodology used for deriving the link types is summarised below:

1. A large number of descriptions of relationships between pieces of text were collected. The function of a relationship had been defined as something that could promote expectation of another piece of text.
2. These descriptions were sorted into self-similar categories, and descriptions of the categories were collected.
3. The similarities between these categories' memberships were calculated. This allowed a hierarchy of clusters of categories to be formed, in which categories were clustered together at different levels of the hierarchy depending on their similarity to each other.
4. This hierarchy was sampled at an intermediate level, giving twelve clusters of categories. These clusters went on to form the final set of relationship types. In each of the clusters, the descriptions given to the categories made up the description of one relationships type.

This methodology for the derivation of the link types has been tested and shown to produce link types that provide a usability advantage. This means that now the individual parts of the methodology can be looked at separately and improved. Sections 1.1 and 1.2 of the next chapter describe how this methodology can be

developed. Section 1.1 argues that the same methodology used here could be used to find links between much larger information units than those dealt with here. Section 1.2 describes how the each of the parts listed above could be developed to improve the link types along the lines which they have been developed so far.

9. CONCLUSION

This chapter has explored several areas to do with the usage and construction of hypertext systems, looking at how the link types proposed in this thesis will affect these areas.

What this chapter shows is that as well as providing the usability benefits identified in the evaluation work described in chapter 5, these links have the potential to influence other characteristics of hypertext usage, and other areas of hypertext development.

This chapter has argued that having a well-defined, general purpose and reusable set of relationship types can bring benefits for users of the systems that incorporate these links. Through using linking methods which are consistent across hypertext systems, they will become practised in their use, making the task of learning to use a new hypertext system easier and causing them to make fewer navigation errors. Moreover, if this consistency causes different hypertext systems to 'feel' the same to the user, they may be seamlessly linked together.

By allowing the development of powerful tools for the construction of hypertext systems, these links can make the authoring task easier and allow it to produce more usable systems. Because the link types can be understood similarly across a group of authors, collaborative authoring of hypertext systems can be carried out using relatively complex links yet still ensuring consistency across the meanings of the links put in place by different authors.

Because the set of links identified in this thesis are complex and descriptive in meaning and yet can be applied across a range of hypertext systems, they lend themselves to being used to describe hypertext systems. This could be on a very simple level (the numbers of different types of links in two systems may allow some comparison), or could be on a more complex level, perhaps allied to descriptions of other hypertext components, such as nodes.

Finally, the methodology for the development of the links is well-defined, meaning that further development of the link types can readily be done.

This chapter has looked at how the relationship types developed in chapters 4 and 5 will affect those areas of hypertext not directly relevant to the main work of this thesis.

The next chapter will look at how this thesis could be extended to enable the link types to be used in practice.

7: Conclusions

This chapter first explores areas where future work is required. It then draws together the rest of the thesis, summarises what has been achieved, and states the conclusions.

1. FUTURE WORK

1.1. Future theoretical work

When the idea of the link types identified in this thesis was put forward in chapter 3, some of the characteristics of these links had to be decided on then, to direct the empirical work of chapter 4. There were areas which could have been looked into further at this stage but which were not, so as to simplify the development of the link types. Three such paths of research which could have influenced the development of the link types are explored here. These are the place of link types such as these in some abstract description of a hypertext system, the inclusion of characteristics similar to those of database relationships in the link types, and how link types for linking large bodies of information could be developed.

One of the things that was identified in chapters 2 and 3 as being necessary for the further development of the potential of hypertext was a more formal way of describing hypertext systems. The contribution that the link types developed in this thesis could make to such a means of description was partially discussed in the previous chapter (section 3.3).

There is a necessity for such a means of description to encode something of the semantics of the hypertext system. This thesis shows that it is possible to have a set of link types that can be used in any hypertext system yet which still conveys something of the meanings of the relationships within the hypertext. This suggests that these link types could form part of this means of description of hypertext systems.

The form that any formal method of describing hypertext systems would take will not be investigated in depth here. It is however, important to make the point that it would greatly add to the power of any abstraction of the hypertext the more aspects of a hypertext system were added to it. A formal representation for describing just the interrelationships in a hypertext only has a certain utility.

For example suppose some aspects of the *content* of the hypertext system were modelled, that is, the content of the nodes. Not only would this bring benefits in itself, such as the ability to search for the presence of certain topics in the nodes, to look at these topics' distribution across the hypertext system, to see how tightly clustered together nodes on the same topic are in the hypertext, and how well linked together different topics are; this would give the user new search tools and tell them something about the large-scale nature of the hypertext system. The combination of representations to describe links and nodes would be useful. It could be seen what topics were linked by what link types, and thus, what the hypertext system was saying about a certain topic.

In addition, extending the representation to areas of the hypertext other than that of link types would bring benefits to hypertext authors and those researching methods of automatic text-to-hypertext conversion. Decisions such as what link to put between two nodes would be based on more information, and could be bought closer to being automated.

As was explained in chapter 3, to simplify the empirical work of this thesis, the relationships developed were designed to be simple, binary relationships. Future work on formalising hypertext links must take into account the work done on the nature of relationships and how this can enhance the expressiveness of hypertext links. For example the attributes of relationships from Kent (1978), summarised in chapter 3, could be used to provide links with such things as constraints on the things they are able to link, different names for their different roles, and so on. For example, using the set of relationships given in the previous chapter (fig. 25), it may be useful for an "Elaborates" link, where information in more than one node elaborates on something, to link more than two objects. It may also be useful for some links to imply the presence of others, in the same way that in Textnet (Trigg, 1983) a "Generalisation" link implies the presence of a "Specification" link in the opposite direction (see table 4 in chapter 3 for a full list of Textnet links).

The methodology used to arrive at the link types put forward in this thesis could also be extended to create link types between larger units of information, such as entire hypertexts, or large topic areas within hypertexts, rather than individual nodes. Information is increasingly accessible, via computer-based tools, from a vast number of computer sites around the world, and this presents problems for those seeking information. First of these is the difficulty in finding what is wanted from the mass of information that is not wanted. Second is the problem of referring to what is wanted when either the way of referring to it is not known or there are a large number of ways

in which it might be named. Third is the problem of knowing what information some name refers to based only on that name. These problems are not simple and are worthy of investigation. Few people can afford the time to sift out all the information they need from that which is available, or to work out how a variety of different information authors have referred to the same thing, or to download many files of unknown size and content in the hope that they might be what is being searched for.

One approach to these problems would be to extend the methodology used for the development of the link types (described in chapter 4) to look at the linking structures needed between large bodies of information. An investigation into the requirements for such links would be needed first. Although some of the needs would be the same as for links within hypertext systems, for example to allow navigation and to communicate the semantics of the link so as to permit users to discriminate among the options available, there are likely to be differences due to the size of the information units being linked, and because these links may connect across networks widely separated in distance. Both of these may affect way in which links are used; if the user is following a link to a large body of information they may be willing to invest more time and effort in making sure that the link they are about to follow is actually what they want. Similarly if the information is held a great distance away the response from activating the link will not be near-instantaneous (as it might be on a small hypertext system). The user may be unwilling to spend a lot of time following links without being sure where they lead (as opposed to when navigating around a small hypertext, where taking such risks is 'cheaper' in terms of wasted time), and will therefore require the link to provide them with more information than it might if it were a link within a small hypertext system.

This section summarises only a few areas into which future research could go, and it is important to note the need for the link types to be developed in their current form to a state in which they could be used in a 'real' hypertext system before these areas are explored. The work required for this is explained in the next section.

1.2. Future development of the relationship types

This section outlines the areas in which future work on the relationship types could be done. The relationship types that came about through this thesis are not in a form in which it would be sensible to apply them to anything other than experimental hypertext systems. As will be shown, a great deal of effort in various areas could be expended in improving these relationships. These improvements were unnecessary for this thesis, in which the goal was to test a stated set of hypotheses, and it would

have been unproductive to do anything not necessary to reach this goal. However, these improvements are necessary if these relationship types are to be used in any 'real' hypertext system where they will need to be more widely applicable, easier for authors to use, and more predictable in their performance.

The future work needed to improve the relationship types as a tool in hypertext divides into three parts, their derivation, including the way the data from the cluster analysis is used to arrive at a set of link types, their evaluation, and the support for the authoring task and how hypertext systems can be constructed using these link types.

The central aim of extending this work on the relationship types is to move from the idea of demonstrating the feasibility of these relationships towards a systematic and investigative study of what characteristics the relationships should have, how they operate, what added functionality they give as a tool in hypertext systems in combination with other hypertext tools, and what the nature is of the benefits they give to the user.

Firstly, the relationship types will need to be more rigorously derived. As was said in chapter 4, they are derived at present from observations of only two different texts, which although different in style, only cover a small part of the range of text types in which these relationships may need to be used. Work will therefore have to be done to derive relationships in the same way from more text types, comparing the results from these different types.

More can be done in the cluster analysis stage, where subjects sort simple descriptions of interrelationships in texts into categories of types of relationship, and then these categories are compared on the basis of their members, and arranged in clusters of categories, each cluster corresponding to a relationship. As discussed in chapter 4, the cluster analysis was a simple operation involving only a few subjects, and a greater number of subjects would possibly result in greater accuracy in this process. In addition, the cluster analysis results in a hierarchy of relationship types which can be sampled at any level to result in anything from one all-inclusive relationship to many highly specific relationships. As was said, for the experiments which followed, this hierarchy was sampled at an arbitrary level near the centre of the range, which resulted in twelve relationships. This stage of the derivation of the relationship types could be investigated, first to discover whether there is a correct level to sample this hierarchy at, for which one would need to know how many relationships subjects could distinguish, and how distinct in meaning subjects preferred the relationships to be. Secondly this area could be investigated to see whether the use of the whole hierarchy of relationship types as a hypertext linking structure was viable. This might

allow authors greater power in choosing the level of abstraction of a certain link, and might allow hypertext users a greater understanding of the interrelationships between the relationship types.

Again at the cluster analysis stage a test could be performed to determine, of the categories that make up an individual cluster (and hence a relationship type) what the similarities between their descriptions are. This was discussed in chapter 4, and would confirm whether the subjects who categorised the responses from the first experiment, as well as sorting these responses into similar categories, thought that these categories meant similar things. If it could be demonstrated that different subjects not only formed similar categories, but also attributed to them similar meanings, this would provide further evidence for the relationship types' meanings being generally comprehensible.

The second area where further development of the relationship types is needed is in the area of evaluation. The experiments in chapter 5 begin this work and show some results of applying the relationship types to a hypertext, but could be extended in a number of areas.

The only task type tested was that of finding the answer to a question for which the user knew that there was a definite answer and that the answer was somewhere in the hypertext system. A wider variety of tasks for which people might use hypertext systems could be tested. For example hypertext users might want to browse a hypertext, to gain a general overview of a subject area or even to look for something whose name they do not know but which they will recognise when they see it. The kinds of tasks that need to be supported will need to be investigated, and then the amount of support that the relationship types this thesis proposes gives them can be evaluated.

The evaluation procedure could be extended to determine the benefit the relationship types give the user. This might examine whether the links help users understand a topic, rather than just with factual information, and whether they improve users' long term memory of what they learn in the hypertext. Another area for evaluation is to determine how easy to learn are the skills of using the relationship types as links. This might measure subjects' transfer of skill from one hypertext containing these relationship types to another. The benefit to the user that is being tested here is whether, by providing general-purpose link types, hypertext systems are made easier to learn to use.

Then, the understanding of the hypertext that these link types provide relative to that provided by other tools must be investigated. Since one kind of hypertext tool cannot

provide all the support the user needs on its own, the benefit these links give to the user must be examined in hypertext environments containing combinations of other tools, with the aim of determining what aspects of hypertext usage different tools support, and the extent to which they complement each other or overlap in functionality.

The third area where further development of the relationship types is needed is in the authoring task. In the application of the relationship types to the experimental hypertext system in chapter 5 the development of an authoring methodology, or guidelines for putting links in place in a hypertext system were not explored, and the reasons for this are given there. However, as discussed in chapter 2, the authoring of a hypertext system is a major undertaking, and the authoring process is spoken of as a bottleneck, obstructing the creation of useful hypertext systems. Therefore, while this thesis proposes a hypertext component which makes hypertext easier to use for the reader, it will not be applied in practice if the authoring cost is too great, and this is why the authoring task must be investigated.

There are three aspects of the authoring task which must be investigated. First, for each link type, can some method be derived which will determine the places in a text where that link type ought to be put. Secondly, how difficult and time-consuming will this authoring process be compared to (a) the authoring of simple unnamed links, and (b) the authoring of typed links specially authored, *ad hoc*, for wherever they are needed in the hypertext system. Thirdly, the possibility of using these relationship types in automatic text-to-hypertext conversion must be investigated.

The first of these points calls for a methodology for determining which relationship types go where in a text. It might at first be thought that since these relationship types are consistent in meaning across people, a relationship type put in place as a hypertext link by one person would be understandable by another. However it may be the case that because authoring and using a hypertext system are such different tasks in which different models of the text may be held by author and reader, the author's placement of links will differ from that required by the reader.

The criteria by which an author should decide to put a certain link in a certain place will not be easy to establish. They will have to take account in some way of the meaning of the text, and without some formal means to describe the text it may be difficult to attain consistency in authoring between authors.

As for the time and cost of authoring, without first knowing about the authoring process, it is difficult to make predictions about how time consuming it will be, although it is reasonable to assume that, since the relationship types are general

purpose and so the process of authoring will not differ from one hypertext system to another, skill at authoring a hypertext will be built up, with a corresponding reduction in the time taken.

The possibility for automatic text-to-hypertext conversion producing hypertext systems which contain the relationship types set out in this thesis will depend on the criteria needed for authoring mentioned above. Only if these criteria are unambiguous in their application can the process be automated.

This section has shown some of the areas where work is needed in order that the link types can be used in the construction of hypertext systems. The least well developed area of work is that of authoring, and because guidelines governing the authoring of these link types are essential if they are to be put into use, it is in this area that research must first be directed.

2. SUMMARY AND CONCLUSION

The field of Human-Computer Interaction deals with the flow of information between user and computer. It is often possible for the computer to store and process much more information than the user needs or wants. So, facilities must be made available to the user to enable them to discriminate from among a vast choice of information sources to get at what is useful or what is pertinent to their current goals. They must be able to do this with software tools provided on the computer and on the basis of information already available to them.

This leads to a distinction between the information the user wants, and information about how to get that information. It is this latter category of information which, this thesis argues is so often inadequately provided in hypertext-like systems. This is an important observation because, as use of computers spreads to fill more and more of people's information needs, the requirement will grow for information systems which, like hypertext, can be easily learnt and which rely on a simple interaction.

Therefore it is important that shortcomings in the support that hypertext systems give their users is investigated, as developments in the sort of system we think of as 'a hypertext system' will influence a wide range of similar systems which rely on a similar interaction with the user.

This thesis argues that current tools to navigate around computer based information are inadequate, in particular the explicit links placed between pieces of information. It examines why these appear to fail in meeting their users' needs and concludes that many of the navigation and comprehension problems associated with them derive from the lack of information they provide to the user. The characteristics these links

might have is examined and the need for a general-purpose set of empirically derived relationships is argued.

The difficulties present in doing a systematic investigation of relational links in hypertext were discussed in the introduction and the decision was made that a feasibility study would be more practical and would allow a better, more informed full investigation to be done later.

This thesis has explored a scheme for adding information to hypertext links and has shown that this scheme provides some benefits for users of hypertext systems. The experimental work for this feasibility study, deriving and evaluating a set of relationships, was described in chapters 4 and 5. The relationships were shown to provide usability benefits in the hypertext system constructed for the experiments, and were shown to allow subjects some expectation of what was linked by them.

It is certain that, despite the success of the theoretical and empirical work described in this thesis, there remains a great deal of work left to be done before the link types could be used in a hypertext system of any size or which would require any sizeable investment of time or money its authoring.

Some of the work necessary before the ideas in this thesis are put into practice has already been discussed in the sections on the future practical and theoretical work needed. To summarise, refinement of the link types developed in this thesis is needed, deriving them from a greater variety of texts, and making them support more of the tasks involved in using hypertext systems. The greatest need however is for research into the authoring of these link types. Without at least guidelines for the placement of these link types in a hypertext system, they will not be used consistently or effectively, and this will impede further development of the link types themselves.

Development of methods of authoring these links will lead to greater usage of the links themselves in hypertext systems, and this will promote research into and development of the link types which will in turn feed into development of authoring methods. Without this cycle of development, the notion of a set of link types as put forward in this thesis will remain at an immature level. There is however urgent need for their development and scope for their widespread use. What this thesis shows is that there is potential for their use in a wide variety of systems and for the success of their continued development, and the theoretical and empirical work they are based on suggest that they will fulfil this potential.

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Appendices

1. APPENDIX 1: THE EXPERIMENTAL TEXTS

1.1. Experiment 1.1: The "Travel" text

1. Perched high up in the foothills of Rinjani, about 9 km from Bayan, this small traditional village seems utterly unchanged from the time it evolved. It exudes a feeling of untainted prehistory that is quite unnerving. In fact it was less than 20 years ago that the villagers of Senaro saw their first westerners, and not many years before that they began to have regular contact with people from the surrounding area. Until then they lived completely isolated from the rest of the world and are still very timid, making no attempt to communicate with strangers and showing none of the overt curiosity that occurs in most parts of Lombok.

2. The village itself is surrounded by a high wooden paling fence and comprises about 20 thatched wooden huts in straight lines, some on stilts, others low to the ground. On the left, just before you come to the village is a small coffee plantation. Unless accompanied by a local person it's polite to ask permission before entering Senaro. Nobody here speaks a word of English.

3. Many of the men from this village work in the nearby forests as woodcutters. Part of the ritual of climbing Rinjani is that guides usually stop at Senaro to stock up on betel nut. Young boys in the village thresh rice with long wooden mallets which reverberate like the sound of drums, adding to the primitive atmosphere. A large percentage of the population, which is less than 500, have goitre due to the lack of iodine in their diet and water.

4. There is a truck that picks up timber from Senaro regularly - usually on Sundays - so you may be able to get a ride down to Bayan on it. In Senaro you should be able to stay with the schoolmaster or at the warung for 1000 rp per person - but don't expect any privacy either way. There's a waterfall 2.5 km from Senaro.

5. Both the Balinese and the local Sasak people revere Rinjani. To the Balinese it is equal to their own Gunung Agung, seat of the gods, and many Balinese make a pilgrimage here each year. In a ceremony they call *pekelan* they throw gold jewellery into the lake and make offerings to the spirit of the mountain. As for the Sasaks some

make several pilgrimages a year - full moon is the favourite time for them to pay their respects to the mountain and to cure their ailments by bathing in the hot springs.

6. Rinjani is the highest mountain in Lombok, the second highest in Indonesia outside of Irian Jaya. At 3726 metres it soars above the island and dominates the landscape. Early in the morning it can be seen from anywhere on the island, but by mid-morning on most days the summit is shrouded in cloud. The mountain is actually an active volcano - thought the last eruption was in 1901 - with a huge half-moon crater, a large slime-green lake, and an extensive network of steaming hot springs said to have remarkable healing powers, particularly for skin diseases. The large caldera drops 200 metres below the rim and there's a new cone in the centre beside the lake.

7. You should not tackle this climb during the wet season as it's far too dangerous. You need three clear days to do it, and probably at least another day to recover.

8. Don't go up during the full moon because it will be very crowded. There are at least two ways of getting up Mt. Rinjani. The first and apparently easier route is via Bayan, Bat Koq and Senaro in the north. The other route starts at Sapit in the east.

9. You can do the trek without a guide, but in some places there's a confusion of trails branching off and you could get lost. The other advantage of guides is that they're informative, good company, and also act as porters, cooks and water collectors. When you're doing this walk with a guide make sure you set your own pace - some of them climb Rinjani as many as 20 or 30 times a year and positively gallop up the slopes!

10. It's worthwhile talking to Mr Batu Bara at the Losmen Wisma Triguna, in Ampenan. For US$75(!) he will organise the complete trip for you - food, tent, sleeping bag and a guide. But if you don't want to come at that he will tell you how to go about it on your own. He'll explain what food to take, and will rent you a two or three person tent for 10,000 rp and a sleeping bag for 7500 rp - steep prices but a sleeping bag and tent are absolutely essential.

11. He will also write a letter to the school teacher in Batu Koq, Raden Kertabakti (known locally as Guru Bakti). He is a very nice man who will not only arrange a guide but also feed you, put you up on the first night and more than likely on the evening you get down from the mountain. To stay here overnight costs around 2500 rp per person. The food is good and there's plenty of it. There are two rooms, in one of the school buildings that have double beds with ground sheets and pillows. There are no toilets here but the children will show you where to go.

12. You need to take enough food to last three days - including food for your guide. It's better to buy most of it in Ampenan, Mataram or Cakra as there's more choice available. Take rice, instant noodles, sugar, coffee, eggs (lots - if you stay at Mr Batu Bara's losmen he will lend you a container to carry the eggs in), tea, biscuits or bread, or some tins of fish or meat, onions, fruit, and anything else that keeps your engine running.

13. It's also a good idea to take plenty of matches, a torch (flashlight), a water container and some cigarettes. The teacher and guide will provide water and containers for you, but it's good to be able to have some handy. Even if you don't smoke, the guides really appreciate being given cigarettes. If you have any food left over, leave it at the school. (From Cummings et al (1986), pp. 572-573).

1.2. Experiment 1.1: The "Pottery" text

1. Clay depends for its usefulness to the potter upon the fact that it can be worked in a plastic state to the required shape and then, by subjection to heat, can be made hard and fixed to that shape.

2. Its plasticity when wet derives from the leaf-like shape of the crystals of one of its constituents - mica. When fired, the expulsion of molecular water will cause shrinkage, and if it were not for the presence of another substance in clay - silica, which does not contract during drying - the work would crack seriously. With too much silica, however, the clay loses plasticity, so obviously the best clay is one with the right proportion of these two constituents.

3. Although suitable pottery clays can be bought quite easily it is interesting, especially in schools, to experiment with clays dug locally, studying results. There is not space in this book to go deeply into the subject of the composition of clays, but such information is easily obtainable in books dealing with this subject alone.

4. Clay dug from the garden can be washed for use as follows - after digging, break into small lumps, removing any stones, put the lumps into a bucket, and cover with water. The clay should then be left for a day or so to soak, and then squeezed and kneaded into a thick creamy consistency, after which it is sieved through a potter's lawn according to the fineness required. A lawn No. 40 will be suitable and useful later for other work, and can be obtained from any supplier of potter's equipment.

5. Clay is often used in this creamy state, and it then known as SLIP. But for ordinary use the clay now requires drying again, and the quickest way to do this is to spread the clay on a dry plaster slab about three inches thick, which will Absorb a good deal of the moisture, and the clay will become plastic again. In the section on

making simple moulds, the reader will find sufficient information for mixing plaster for making such a slab.

6. A further operation remains before the clay is in condition for use, and this is known as WEDGING. This is usually done in England by banging the clay down onto a clean, firm bench or table, forming it into a brick-shaped lump. This banging forces out any air which may remain in the clay. The lump should then be cut in half with a wire as if it were cheese, the two halves pressed together again with the cut surfaces facing outwards, and then banged hard into a brick shape once more. This should be cut again, and the process repeated until no uneven consistency of the clay remains, and it is smooth throughout. Clay must always be wedged before proceeding to work with it.

7. For storing the clay when not in use, we need some type of bin in which it can be kept moist. For school work a dustbin is suitable; for smaller quantities any water-tight container of convenient shape, which has a lid and will not rust, will do. Some pieces of board should be placed over the bottom of the container, raised by bricks or blocks of wood, so that water can be kept at the bottom of the bin and the clay in a sack above this. The sack covering the clay should be kept moist and the lid kept on the container.

8. For different-coloured clays, separate containers will, of course, be required, and it is useful for having one for soaking old clay which has gone hard. This can be reconditioned in the way described for washing clay.

9. Very frequently work which has not been finished needs to be kept moist for working on another occasion; in school a number of biscuit-tins can be stacked for this purpose, with their lids off, rather like lockers with no doors. Damp sacks can be hung across the openings, and the work kept inside, each piece wrapped in a damp cloth. The work must be watched if not worked on for a matter of days, and the cloth kept moist. To prevent rust, the tins should be painted inside and out. For home use a similar but smaller contrivance can be made one biscuit-tin or suitable container will probably be sufficient. (From Tyler (1952), pp. 11-15).

1.3. Experiment 2.2 text.

1. The process of mending a puncture on a general level is this: First check the wheel for obvious causes of puncture and then, if necessary, remove the wheel and find, possibly by immersing the inner tube in water, the point at which the inner tube is punctured. When this is found, prepare the surface around the point of the

puncture, apply the patch, reassemble the wheel and, when the patch has dried, reinflate the tyre.

2. The first thing to ask is: Does your bike really have a puncture? If a tyre is only a little bit soft, or if you have not used the bike for some time, it may be OK. All tyres need a bit of pumping up now and then.

3. Most punctures are not caused by very obvious things like nails, pieces of glass, etc. However, if your puncture is caused by something like this, and it is still embedded in the tyre, finding it will not only make the puncture easier to deal with, but is also necessary to prevent the puncture reoccurring.

4. As a reminder, here is a quick guide to the parts that make up a wheel. At the centre is the *hub*, which doesn't concern us so much for the purpose of puncture repair. The *spokes* connect the hub to the *rim*, so that when the bicycle is moving, the hub is suspended from the spokes connecting the hub to the top of the wheel. The ends of the spokes at the rim are threaded, and nuts screwed onto the spokes both hold them onto the rim, and can be used to adjust the tension of the spokes. The *inner tube* sits inside the rim, and there is piece of *tape* protecting the inner tube from the ends of the spokes sticking through the rim. Finally there is the tyre, the edges of which fit inside the rim. The *valve* on the inner tube sticks through a hole in the rim, and will have a nut on it screwed down to the rim.

5. You will need various tools to repair a puncture. A bicycle spanner, usually a box spanner, may be needed to take the wheel off (unless you have quick-release wheels). Tyre levers will be needed to take the tyre off the wheel, and to actually repair the puncture, rubber solution (or vulcanising solution), patches (the best patches are Cure-C-Cure patches), Wet-and-Dry sandpaper, and chalk.

6. Punctures are generally caused by one of five things: (i) There is something on the road, e.g. glass, which punctured the tyre, and may still be embedded in the tyre; (ii) Usually from riding over potholes, the tyre was pinched against the rim, and the inner tube split; (iii) One of the spokes sticks too far through the rim, or the tape is ineffective, and the spoke punctured the inner tube (This usually results in a series of pinprick-like holes on the rim side of the inner tube); (iv) The inner tube was pinched by your tyre levers the last time you mended a puncture, and this damaged it; (v) The inner tube is old, and the rubber is starting to perish and disintegrate.

7. If you can see what caused the puncture, you are lucky because this makes your job a lot easier as you will not have to remove the wheel. Mark with chalk on the tyre where the puncture is, and then remove the object from the tyre. Then make sure the tyre is fully deflated, and lever one side of the tyre off the rim with tyre levers to a

distance of about 12 inches along the rim either side of the puncture. This will allow you to get the punctured bit of inner tube out and repair the puncture.

8. If you don't know where the puncture is on the wheel, you will need to take the inner tube out, and this involves removing the wheel. However it is easier to lever the tyre off the wheel when it is still on the bike, so do this first, levering the tyre off one side of the rim only with tyre levers, and being careful not to pinch the inner tube. Then to remove the wheel, first loosen the nuts on the axle, or if you have quick-release wheels, simply move the lever on the axle away from the wheel. If you are removing the front wheel, it should now be easy to lift out (the bike should be upside down to do this); if you are removing the back wheel, you will have to bend the deraillieur cage back to lift the wheel past it, and then move the chain to one side.

9. If you have levered one side of the tyre off the rim, it should be easy to put your fingers between the rim and the tyre at some point and pull the inner tube out. The only tricky bit is taking the valve out.

10. With the inner tube out, you can then pump it up slightly and listen for the hiss of escaping air. Unless it's a very slow puncture, if you carefully listen to the inner tube, moving it slowly past your ear, you will hear something. If you think you've found the hole, put a small blob of spit on it to check (the spit will bubble slightly), and check to see that there are no other holes in the tube (there may be one very close - whatever caused the puncture could have gone right through both sides of the inner tube).

11. If you cannot find the puncture by listening for the hiss of escaping air, you will have to pump the inner tube up, immerse it in water, and look for bubbles of air coming from it.

12. When you have found where the puncture is, the surface of the inner tube must be prepared. First dry the surface of the inner tube, then roughen it with a piece of Wet-and-Dry sandpaper or something similar. Let all the air out, and make sure you have roughened an area larger than the patch you are going to use.

13. Then spread a thin layer of the vulcanising solution (also called rubber solution) to the inner tube around the puncture, wait for this to dry (a couple of minutes) and apply the patch, making sure there are no air bubbles caught under the patch. When you have waited for this to properly dry (about 20 minutes), put chalk on any excess rubber solution on the inner tube (to stop it sticking to the tyre).

14. Putting the tyre and wheel back on is the reverse process of taking them off. Put the inner tube onto the rim, and then put the wheel back on the bike, making sure that the nuts holding it on are done up tight. Put as much of the tyre back onto the rim

with your hands as you can, and then do the rest with tyre levers. It is important to be very careful not to pinch the inner tube with the tyre levers when putting the tyre back inside the rim. After this, screw the nut back onto the valve, so that it is held firmly against the rim, and inflate the tyre.

2. APPENDIX 2: STUDY 1.1 INSTRUCTIONS

Experiment instructions - read carefully

This experiment is designed to see what sort of relationships you can see between paragraphs of information. It is anonymous - for the purposes of the experiment you will be known by a letter - and should not take long to complete (- if you would rather, you can complete it in your own time, having first read and understood the instructions on this page).

What is meant by a "relationship" between two paragraphs? - This relationship should be such that if you were given the first paragraph and the relationship, you would be able to go some way towards anticipating the content of the second paragraph.

You will be given two sheets of paper, each with numbered paragraphs. One has a section taken from a travel guide on it, and the other a section taken from a book on pottery.

For each of these sheets you will be given a number followed by a list of numbers. Your task is to write down any relationships you can see between the paragraph marked by the first number and those marked by each of the numbers in the list. For example if you were given:

"Pottery: 3: 2,4,6,8"

- you would look (in the text on Pottery) for relationships between paragraph 3 and paragraph 2, then between paragraph 3 and paragraph 4, then between paragraph 3 and paragraph 6, and finally between paragraph 3 and paragraph 8.

Subject: ☐

1. Answer the questions below.

Have you used travel guides before on holiday/ Are you familiar with their style and format? (tick one box) Are you familiar with practical pottery, in particular, clay preparation and storage?		
	Travel Guides	Pottery
Frequently/ very familiar	☐	☐
Often/ familiar	☐	☐
Sometimes/ slightly familiar	☐	☐
Hardly ever/ not familiar	☐	☐
Never/ Completely unfamiliar	☐	☐

2. Read each of the texts.
3. For each of the paragraph pairs you are asked to look at, write down what relationship you perceive.

- If you cannot see any relationship between the paragraphs, write this down
- If you can see a relationship, write this down, being precise about (i) what it is about the paragraphs that is related, and (ii) the nature of the relationship.
- If the relationship can be expressed without using terms from the text, try to do this.
- If the relationship works in one direction but not the other, indicate this.

Thank you for sparing the time to do this experiment.

3. APPENDIX 3: STUDY 1.1 RESULTS

The following sections (3.1 and 3.2) show the responses to the study described in chapter 4 (Experiment 1.1) in which subjects were asked what the relationship was between the paragraphs. Section 3.1 shows the responses to those paragraph pairs taken out of the "Travel" text (reproduced in appendix 1.1), and section 3.2 shows the responses to those paragraph pairs taken out of the "Pottery" text (in appendix 1.2). For each paragraph pair, all the responses for that pair are listed.

3.1. Travel text

Travel text: Paragraphs 1 and 2

[1] Both paragraphs are discussing the same village. Both paragraphs have the same Subject matter.

[2] 1 & 2 refer to the same village, Senaro. 1 perhaps gives temporal perspective, while 2 is more on location. Both refer to the relations between locals and westerners. 2 is more directly stating what the visitor should do to enter. Main relationship is elaboration. 1 & 2 provide description of same place. Not one way.

[3] Continuous - Expansion - One directional

[4] <-> Both talk about the village

[5] 1 introduces the village, and 2 makes a 'back reference' - "the village itself". The implication is that an introduction has been read.

[6] Link is the village of Senaro

[7] Nature of relationship: subject matter - location - same village. characteristics of Senaro. Characteristics of the people. Related: Senaro (1 & 2).

[8] There is a weak relationship. They both talk about small villages. the relationship only really works from 1 to 2

[9] same topic - one more detail following from the other - bi-directional

Travel text: Paragraphs 1 and 4

[10] Both paragraphs are discussing different aspects of the same village - i.e. 1 is discussing the geography and history, 4 is discussing how to get to it. Both paragraphs are dealing with different aspects of the same Subject

[11] Para 4 is elaborating on the visitor to Senaro - what the visitor can do there, what other places can be visited, where he/she can stay. 1 might introduce Senaro, 4 expands on the activities available; lodgings available. (One way).

[12] It is a bi-directional context-dependent relationship. Mainly we can see 4 as an elaboration on Senaro. So 1 contains historical and geographical information,, while 4 is how to get there and where to stay.

[13] There is a relationship - both talk about the villages of Senaro and Bayan. Para 4 expands on Para 1 by describing how to travel between the two places.

[14] (1<->4) Both mention Senaro

[15] Link is still the village of Senaro

[16] Weak relationship in that 1 introduces village of Senaro which is the Subject of para 4. Para 1 gives background info about Senaro - but there is no way to anticipate content of para 4 from 1 or vice versa

[17] That village is 'high up' on foothills (position). That Bayan is 'beneath' it - lower down (position). An 'opposite' relationship: 'untainted' isolation of para 1 with lack of privacy at school master's house (or

warung?) in 4. "Regular" (1), "Regularly" (4). Senaro mentioned in both paras. Distance mentioned in both paras (9km (1), 2.5 km (4)).

[18] 1 has a relationship to 4 in that 4 talks about Senaro as if it were an interesting place, and 1 explained how interesting it is. Maybe the order of reading would be 1 and then 4 because you want to find out about the place first before finding out about accommodation arrangements

Travel text: Paragraphs 1 and 6

[19] Both paragraphs make reference to a particular mountain (Rinjani) paragraph 1 merely mentions the name, paragraph 4 discusses the mountain in more depth. Paragraph 1 makes reference to a particular Subject, and paragraph 4 expands on it. One way relationship.

[20] Both Rinjani and Lombok were used in 1 to position Senaro, and one then elaborated in 6 to provide a description of an interesting landmark. Relationship with 1 is tenuous, perhaps there is some visual stimulation. One way.

[21] No relation

[22] 1 describes the inhabitants of the region where the mountain in 6 is located. 1 gives background information about 6

[23] (6->1) 6 introduces Rinjani, and 1 mentions Senaro as a village that happens to be on Rinjani

[24] The link is the region of Lombok and mount Rinjani

[25] 1 refers to a place to visit if you're in the region of Rinjani

[26] Relationship - both describe aspects of the same place - Lombok

[27] Geographical references, relationship H3: from 1 to 6 as 6 provides further geographical explanation in detail on main subject

[28] The relationship is that both paras are describing details about places, with para 1 describing the location and some history, and para 6 delving into details like dimension, geography and folklore

Travel text: Paragraphs 1 and 8

[29] Both paragraphs make reference to the same Subject (Mt. Rinjani). This is the main Subject of para 8 but only mentioned in para 1. Both paragraphs make reference to the same village. It is the main Subject of para 1 but only mentioned in para 8. One way relationship.

[30] - most closely relates to 7 but as this missed, a relationship can be drawn from 1 because Senaro provides a route up the mountain (1 - route to Rinjani - 8) or (Senaro - (8) route to - Rinjani)).

[31] No relation

[32] Mention Bayan

[33] None. The notion of the villagers being very timid, and it being very crowded at full moon are contradictory.

[34] The mountain Rinjani is the only link

[35] A relationship of travelling - but this is only apparent because I read all 13 texts. Weak relationship

Travel text: Paragraphs 1 and 10

[36] No relationship

[37] None of the proper nouns are used, but assume reference to trek up Rinjani (1 - Organising a trek up Rinjani - 10).

[38] no relationship seen

[39] (1->10) 1 introduces where to go and 10 gives practical help on how to go about it.

[40] No link here

[41] From someone connected (very much) with society to a description of people with little or no connection with western society

[42] no relationship
[43] Both give facts about something

Travel text: Paragraphs 1 and 12

[44] No relationship
[45] Relation of 12-1 supports 10-1 (i.e. 1 - acquiring supplies for the trek up Rinjani - 12).
[46] Point of ref. - Mt. Rinjani
[47] works one way, from 1 -> 12, though it's not exactly a follow on
[48] None. The back reference to "Mr Batu's place means that any connection is lost.
[49] No, not one here either.

Travel text: Paragraphs 2 and 3

[50] continuous - expansion - one directional - (expands info about the village and its habitants)
[51] -> Both talk about the village. It is only one way, as 3 starts with back references like "This village..."
[52] none
[53] relationship exists both ways - the relationship is village life
[54] Nature of relationship: The people of Senaro. Extended geographical area of Lombok. Related: no-one speaks English - pop. less than 500
[55] There is no relationship since 2 talks about the buildings etc. of the village, and 3 talks about the people
[56] Describe village life - bi-directional
[57] Reference to the village expands the description
[58] same topic, but 3 really only follows from 2
[59] 2->3: 2 reads as a preamble to 3

Travel text: Paragraphs 2 and 5

[60] continuous - expansion - one directional - expansion about villagers
[61] None
[62] no identifiable relationship
[63] home, para 2 seems to describe the home of the people in para 5, but it is not certain as the info in 2 does not mention the 'people' or 'tribe'
[64] Location in Lombok - Senaro/ Rinjani
[65] No relationship
[66] Can't see a relationship
[67] No obvious relationship without further information.
[68] no relationship

Travel text: Paragraphs 2 and 7

[69] none
[70] None
[71] No relationship
[72] none
[73] none
[74] No relationship
[75] No relationship at all
[76] No relationship, 7 is talking about doing the climb, 2 about a village
[77] no relationship

[78] No relationship

Travel text: Paragraphs 2 and 9

[79] none

[80] -> The connection is the use of guides (as communicators in 2 and navigators in 9) Only one way, as 9 does not mention the village, and so the connection is broken.

[81] The advantages of a guide

[82] Both mention advantages of being accompanied by a guide/ local person. Both give useful advice/ information - otherwise, not closely related, except village is near start of trek up mountain.

[83] location - Lombok

[84] No relationship

[85] none

[86] none

Travel text: Paragraphs 2 and 11

[87] descriptive/ expansion - one directional: life at the village for travellers.

[88] None - the back reference to "He" breaks the connection 'guides'

[89] 2 sets the scene and is mainly descriptive and develops in 11 into practical instructions on how to cope. Descriptive -> Instructive (2->11)

[90] No relationship

[91] No connection (Contradiction in para 2 - ask for permission, yet no-one speaks English)

[92] no relation

[93] no relationship

Travel text: Paragraphs 3 and 4

[94] none

[95] a relationship exists - on visiting Senaro ...info about village life relationship - either way

[96] 3 is a bit of extra background on Senaro. It doesn't seem to stand on its own, so we can say that 4,3 is an explanation 4->3

[97] There is a relationship - both mention Senaro and refer to the "industry" of the area.

[98] accommodation in Senaro 3 -> 4

[99] Refers to the timber cut by the men

[100] Again, little of a relationship - can't predict content of 4 from 3 or 3 from 4. Only content related is about woodcutters and truck that picks up timber

[101] Height - climbing (3), going down to Bayan (4). Senaro mentioned in both. Water (3), waterfall (4). forests/woodcutters (3), timber (4). guides (3), schoolmasters (4). boys(3), person (4). reverberating drum sound (3), continuous sound (4) of waterfall. Distance - nearby forests in (3), waterfall 2.5 km in (4). Numerals - 500 in (3), 1000 in (4). Mobility - climbing (3), truck (4).

[102] (3<->4)? Difficult relationship because the structure of para 3 is disorganised. 4 might be read as developing one of the topics mentioned in 3. 3 might be read as expanding on the topic of 4

[103] 3 has a relationship to 4. Same comments as for 4:1 (D3: 1-4), except 1 reads more like an intro. to Senaro. Also 3 is ... "non-travel-guide" - info about goitre, etc.

Travel text: Paragraphs 3 and 6

[104] Explains what Rinjani is

[105] Here is a relationship - the mountain, but only a weak relationship, because #3 is about village life, and #6 is about the mountain.

[106] No relation
[107] 3 describes a typical journey (one part of it) up the mountain. Assumes the reader will want to climb it, and gives background information
[108] Explains Rinjani - 3 <-> 6
[109] Refers to the mountain Rinjani - expands description
[110] 3 refers to the ritual of local people in the region of Rinjani
[111] Relationship - the mountain Rinjani (6->3)
[112] 3->6: 6 resolves an otherwise unexplained reference in 3 ("Rinjani")
[113] Both paras describe something. para 3 describes life in the village while para 6 describes the mountain and its features

Travel text: Paragraphs 3 and 8

[114] Advice on climbing Rinjani
[115] a weak relationship again - just the noun, Mt. Rinjani & climbing it; this relationships a bit stronger than 3-6
[116] No relation
[117] Senaro
[118] Describe a different way of getting up Rinjani 3 -> 8
[119] Refers to climbing the mountain - the route to use
[120] Again a tentative relationship. Mountain is the only relationship really
[121] no apparent relationship

Travel text: Paragraphs 3 and 10

[122] Advice on organising the trip
[123] no relationship
[124] no relationship seen
[125] How to organise the trip 3 -> 10
[126] No real relationship - possibly about organising a trip yourself, as guides are mentioned in para 3
[127] from how *you* survive to how the natives survive
[128] Both paras mention guides, but there is no other relationship
[129] no apparent relationship
[130] give facts

Travel text: Paragraphs 3 and 12

[131] organising provisions
[132] no relationship
[133] Para 12 - prep for climb which will go to village in para 3, as guide in 12 will probably stop off here (3). NB contrast - malnutrition of village inhabitants + nutritious food passing through it by tourists
[134] no significant relationship
[135] Which sort of food and where to get it 3 -> 12
[136] More about organising a trip - no real relationship
[137] 3 <->12 ironic contrast between final comment in 3 and recommendation in 12!

Travel text: Paragraphs 4 and 5

[138] no relationship
[139] There is no clear relationship (Except within the context of the overall text discussing Senaro).
[140] again - no clearly identifiable relationship

[141] visiting, tells you how to visit the people
[142] No relationship
[143] regular arrival of truck (4), regular pilgrimage of Balinese (5). Lake (5), waterfall (4). Height suggestion in (4) - "down to Bayan", in (5) - mountain. liquid - hot springs in (5), waterfall in (4)lack of privacy in (4), pilgrimages (people) in (5). Nature - moon, lakes, hot springs, mountains (5) - timber, waterfall (4)
[144] There's a mountain and a lake in 5 and a waterfall in 4. Could describe similar or nearby places
[145] No obvious relationship without further information.
[146] 5 has no relationship to 4
[147] no relationship

Travel text: Paragraphs 4 and 7

[148] You could say that 7 is a continuation of 4, and could be referring to the climb to the waterfall. It definitely is context dependent.
[149] As for 4-5 (H: 4-5), plus it is clear that both paras are part of a travel guide of some sort.
[150] No relationship
[151] none
[152] No relationship
[153] Height/ distance - "down to Bayan" (4) - "climb" (7). Writer in 2nd person. sing/plural. in both paras. Water. Travel
[154] No relationship at all
[155] 4 is talking of how to effect the climb, discussed in 7. No relationship. from 7 -> 4
[156] 7 has no relationship to 4
[157] No relationship at all

Travel text: Paragraphs 4 and 9

[158] Same as above (G: 4-7). 9 follows 4.
[159] As for 4-7 (H: 4-7)
[160] No relationship
[161] Both give advice/ warning ("make sure you set your own pace", "don't expect any privacy"). Both mention transport/ route - Trek, walk trails/ truck, ride to Bayan
[162] No relationship
[163] Guide-schoolmaster. water-waterfall. ride-walk, gallop. Height. Numerals. Possibilities. Paths/routes. People. Possibilities of communication
[164] none
[165] none
[166] 9 has no relationship to 4

Travel text: Paragraphs 4 and 11

[167] They could be related, but then they would be inconsistent in the pricing. Therefore they are not related (just because of the content).
[168] There is a relationship, whose Subject is "accommodation with school teachers".
[169] Both refer to the schoolteacher
[170] Both lists of practical instructions
[171] No relationship - in fact worse - anaphoric reference in 11 confuses after pronouns in 4.
[172] schoolteacher/ schoolmaster. Provision of accommodation. Travelling downwards. Number of rupiah. Time. The numeral '2'. 2nd person. pl./sing.

[173] No connection
[174] link: price comparisons/ schoolmaster in Batu Koq vs. schoolmaster in Senaro. - also privacy comparisons. Nature of link: comparison of similar info
[175] 11 has a relationship to 4 but repeats information in a different form concerning school teachers (therefore reading 4 then 11 would not be appropriate). Also it's not clear from reading 11 alone who "he" at the start of the para refers to. Only by reading 10 would you know.
[176] It's much more expensive to stay in Batu Koq than Senaro

Travel text: Paragraphs 5 and 6

[177] relationship - is link with Rinjani - i.e. the people's feelings toward Rinjani & geographical and morphological description of Rinjani.
[178] places of interest; once established, the visitor can see this location
[179] Relation is the ability to heal diseases (<->)
[180] 5 gives cultural significance of the mountain - more background information (This was also one of the paragraphs of which this Subject said: "These relationships rather assume that the paragraph 6 motivates the reader to climb the mountain. Those readers with no wish to climb would probably say differently")
[181] One paragraph describes physical setting, the other describes activities and beliefs at that place
[182] People <-> Mountain (location of people) relationship.
[183] This is a two-way relation between the description of the mountain and belief of the people with respect to the mountain
[184] Relationship - the mountain Rinjani (6,5)
[185] Both refer to Rinjani. In 5 it is not clear what Rinjani is - I thought it was a holy city in which the mountain was situated, but 6 elucidates on this, and makes t clear that Rinjani is a volcano, also there is ref. in both to the holy lake
[186] The relationship is the mountain, and certain other features are mentioned in both paras

Travel text: Paragraphs 5 and 8

[187] Some relationship by reference to Rinjani, but less than 5-6
[188] details of places of interest
[189] No relation
[190] Both mention full moon
[191] Both paras refer to Rinjani and at least one thing that happens there.
[192] How you get there =8, who you meet =5.
[193] Tentative relationship: Mountains, again but a little more obvious in the relationship of pilgrimage and tourism
[194] Both refer to Rinjani & the full moon as being the best time for pilgrims (para 5) and the worst for tourists (para 6)

Travel text: Paragraphs 5 and 10

[195] no apparent relationship
[196] details of places of interest, how to get there
[197] no relationship seen
[198] Can't see any relationship
[199] No obvious relationship without further information.
[200] Description of how to achieve your pilgrimage -> how the natives achieve theirs
[201] no relationship

[202] The only relationship is that in para 5 the mountain is mentioned and in para 10 one is advised on the best arrangements which can be made for climbing it
[203] again they both give facts

Travel text: Paragraphs 5 and 12

[204] again no real link (force a link with pilgrimage, but is not actually specified.
[205] details of places of interest, trip details
[206] Only ref. implied - difficulty in climb - locals it's a pilgrimage, tourists not
[207] Could quite easily go both ways
[208] Can't see any relationship
[209] No obvious relationship without further information.
[210] Both paragraphs suggest Mr Batu Bara as an expert on the mountain trip; he will organise everything including a guide, which is mentioned in both paras. Both mention Ampenan

Travel text: Paragraphs 6 and 7

[211] Both paras seem to be talking about the same mountain
[212] 7 gives a practical warning about climbing the mountain. Practical advice. (This was also one of the paragraphs of which this Subject said: "These relationships rather assume that the paragraph 6 motivates the reader to climb the mountain. Those readers with no wish to climb would probably say differently")
[213] 6 describes the mountain, 7 warns of some of the difficulties of climbing it
[214] describes a mountain (volcano) which relates to climbing. It's height relates to the time it takes to climb (m mentioned in 7)
[215] 6 to 7 describes a route while 7 is a warning
[216] Relationship - the mountain Rinjani (6,7)
[217] Presumably 7 is speaking about the mountain in 6, but this is not specifically clear
[218] 6 describes the mountain. 7 assumes you want to climb it. A relationship both ways - dependent on the other.
[219] para 6 hints as to why one would want to attempt an event, and para 7 gives advice on partaking in the event (or journey) Other than this vague relationship I see no other
[220] Not possible to infer para 6 from 7 but 6 may provide further reasons for the statements of 7

Travel text: Paragraphs 6 and 9

[221] Obviously they're talking about the same mountain. Both seem to hilight the difficulty of climbing it (<->). For some strange reason I did not feel that point for 6-7 (K1 6-7)
[222] 9 - Practical advice on climbing the mountain
[223] Rinjani - the name but nothing else
[224] 6 describes mountains (gives an idea of the size and dangers "shrouded in cloud... last eruption") 9 describes how to climb it, suggests taking porters because of difficulty and length of climb (one way 6->9)
[225] none
[226] Relationship - the mountain Rinjani (6,9)
[227] a description of the trek - works better from 6-9
[228] none
[229] Apart from the obvious relation - i.e. the object - mountain, there is no other

Travel text: Paragraphs 6 and 11

[230] Yes, but a weak relation. Again the relation is centred on the same mountain.

[231] 11 detailed information about where to obtain guides & accommodation. Specific information. (This was also one of the paragraphs of which this Subject said: "These relationships rather assume that the paragraph 6 motivates the reader to climb the mountain. Those readers with no wish to climb would probably say differently")
[232] Both make reference to the mountain/ volcano
[233] Instructive <- Descriptive (11 <- 6)
[234] none
[235] no relationship
[236] No connection
[237] no relation
[238] no relationship
[239] no relationship

Travel text: Paragraphs 7 and 8

[240] First sentence of 8 is a continuation of 7
[241] don't climb in the wet season relates to don't climb at full moon (when to climb). 8 describes how to do climb
[242] Relationship present
[243] Both on when not to climb mountain
[244] 8 is going into more detail about the subject of 7
[245] How to do the climb and when. Relationship better 7 -> 8 than 8 -> 7
[246] Obvious climbing relation, two way relation, the order does not matter since the link is so apparent
[247] Might be able to infer from 7 & 8 together that they are describing different mountains, as if you can climb it at full moon it would take less that 3 days; if it could be climbed at full moon it would be an easy climb

Travel text: Paragraphs 7 and 10

[248] No relationship
[249] 10 describes the best planning for the climb
[250] no relationship seen
[251] 10 is enlarging and giving a more positive aspect to the second sentence in 7
[252] Another two-way relationship. Both assume you want to do the climb. 10 is more specific than 7
[253] What equipment you need -> what amount of time you need - a physical to temporal relationship
[254] no relationship
[255] Can't infer 10 from 7 although it might be possible to infer bits of 7 from 10 - i.e. that the suggestion to organise a guide implies an element of difficulty/ danger
[256] they both give advice

Travel text: Paragraphs 7 and 12

[257] 7 warns the climb will take 3 days, and 12 describes how to plan for that.
[258] 3 days to climb - take food for 3 days - planning
[259] Length of time for climb - para 7 -para 12 - amount of food needed
[260] Could quite easily go both ways
[261] 10 is enlarging and giving a more positive aspect to the second sentence in 7
[262] Relationship. between 7->12, but not 12 -> 7. 12 is more specific on detail than 7.
[263] The suggestion that the climb takes 3 days in 7 implies immediately that you will need food (12) so the relationship is ?

Travel text: Paragraphs 8 and 9

[264] None

[265] Climbing Rinjani

[266] Both give advice/ warning ("You could get lost"/ "don't go up during full moon"). Both concern how to climb mountain. 8 mentions different routes -> 9 advises to take a guide

[267] Relation is there as it speaks of trails (routes)

[268] Again the climbing/ trip relationship 8<->9

[269] good relationship 8-9

[270] none

Travel text: Paragraphs 8 and 11

[271] Very slight relation as it mentions a guide

[272] Batu Koq

[273] Both refer to Batu Koq

[274] Both lists of practical instructions

[275] Not obvious until the middle of para 11. Seems to sway for 8 -> 11, but not the converse

[276] Only connection is Batu Koq

[277] link: location of Batu Koq on routes to Mt. Rinjani - Nature: establish relevance

[278] A reason to stay in Batu Koq/ details of how to climb the mountain

Travel text: Paragraphs 9 and 10

[279] Guides

[280] Close relationship - 9 is about guides in general; 10 is about a specific guide. Both give useful advice/ information

[281] The relationship between the paragraphs is the advantage of hiring a guide. Para 10 provides info about the costs and services offered by hiring a guide which leads the reader to anticipate more info about what else the guide offers and if he is really necessary, which appears in para 9. (9<->10)

[282] 10 follows from 9 quite nicely in its description of how to get a guide

[283] none

[284] How much your guide/trip will cost -> what your guide will do for you

[285] both paras discuss guides. It seems that para 9 follows from para 10

[286] Both give facts and advice

Travel text: Paragraphs 9 and 12

[287] FOOD THAT YOUR GUIDE WILL COOK

[288] Both are about how to climb mountain. 9 is about guides, 12 is about food to take 10 is more specific - what food, how much, where to buy it

[289] Importance of guides - food they cook in 9, listed in 12

[290] Could quite easily go both ways

[291] 12 follows from 9 in its discussion of time and a guide

[292] none

Travel text: Paragraphs 10 and 11

[293] the relationship between the paras are the services and help you can obtain by talking to a certain local man. Para 10 introduces us to the man, and to what help & advice he can give as well as the costs. para 11 then continues to tell us how this local man can introduce us to other locals who can also provide

accommodation, guides, etc. for a certain price. The relationship works in this direction only because we need to be introduced to the first local man before understanding fully what is being said in para 11
[294] Both refer to organising local guides
[295] Both lists of practical instructions
[296] How much Mr Batu charges -> what he will do for you and a comment on his character. Also what to expect from the accommodation provided
[297] Both of these paras discuss guides and food and the prices for renting items or for accommodation
[298] regarding info about the guides after info about accommodation
[299] link: amplification of Batu Koq's services. Nature: amplification
[300] Both give facts/ refer to the same person/ give opinions
[301] The person who can arrange things for the trip - Batu Bara

Travel text: Paragraphs 11 and 12

[302] Both refer to organising local guides
[303] Both lists of practical instructions
[304] Mr Batu Bara's losmen & his services
[305] slight link 11-> 12 but not vice versa
[306] contradiction, as food will be served at accommodation, but para 12 says take lots of food
[307] no relation
[308] no relation

3.2. Pottery text

Pottery text: Paragraphs 1 and 2

[309] 2 is an explanation/documentation of 1
[310] There is a relationship. Both discuss clay & more importantly 2 expands on the state of the clay mentioned in 1 (esp. Its plasticity)
[311] some link between them - i.e. initial intro. on clay (can't read) properties of plasticity with 2 describing how plasticity is formed within clay
[312] details, para 2 gives details about the process involved in para 1
[313] statements of fact in para 1 are expanded into para 2 - reasons for plasticity, effect of heat etc. given. Both paras the same, but para 1 concise, giving idea - para 2 as above, but more confusing. Stand alone, but not repetitious - complement each other
[314] relationship between plasticity & hardness i.e. paragraph 2 expands p. 1 -> reason for the different textures
[315] Para 1 introduces the notion of plasticity, Subject matter which is followed up in para 2. The relationship is one sided i.e. 1 to 2
[316] Plasticity/ Plastic state - consistency. - Subjection to heat/ expulsion of water - drying out process. Process from one state to another - para 1 = short general overview, para 2 = detailed process
[317] Para 2 explains reasonably scientifically how the constituents of clay make it the substance described in para 1
[318] Related by plasticity, 1 requires a degree of plasticity, 2 describes the causes of plasticity. 2 far more specific.

Pottery text: Paragraphs 1 and 4

[319] Expansion - one directional (expands on why clay is useful to pottery)
[320] Clay must be able to be worked into a plastic state, and 4 explains how to do this.

[321] none, other than reference to clay
[322] practice, para 4 tells us some details about obtaining and using the stuff in para 1
[323] No relationship
[324] only in terms of subject matter i.e. clay -> there is no (can't read)
[325] subject matter/ the different states of clay/ How external properties affect clay/ Different consistencies of clay/ The potter
[326] There is a relationship, but it is weak. They both talk about using the same material. The relationship, such as it is, works either way
[327] Para 4 is instruction about how to begin to prepare clay to be used as the substance in para 1
[328] 4 talks about methods of preparation, 1 about the more general use of clay, therefore 4 subsidiary to 1
[329] Only connection is clay> No commercial connection as 1 describes potter's clay & 4 describes home made clay. Makes more sense if para 4 is read after para 1

Pottery text: Paragraphs 1 and 6

[330] none, other than reference to clay
[331] practice as 1-4 (J: 1-4), preparation
[332] There is a relationship, as both relate to clay's preparation
[333] None
[334] The relationship between the paragraphs is preparing the clay in order for it to be ready for use. Paragraph 6 tells us how to wedge the clay in order for it to be ready for use, which leads the reader to anticipate why and what happens to the clay after wedging, which is very briefly explained in para 1. The relationship works in both directions because para 1 states that the clay must be worked, heated and then shaped, and para 6 then continues to talk about working the clay
[335] only in terms of subject matter i.e. clay -> there is no (can't read)
[336] Para 6 describes a further technique to prepare clay for a potter's use
[337] 6 talks about methods of preparation, 1 about the more general use of clay, therefore 6 subsidiary to 1
[338] No obvious relationship except both about clay!
[339] No relationship apart from clay

Pottery text: Paragraphs 1 and 8

[340] none, other than reference to clay
[341] practice as 1-4 (J: 1-4), life-cycle
[342] Well, both talk about the clay, but no real relation between them (also see K1 3-8)
[343] 8 describes how the plastic state described in 1 can be restored to old clay. 1 gives the motivation for doing what is described in 8
[344] No relationship
[345] only in terms of subject matter i.e. clay -> there is no (can't read)
[346] Both paras are about clay use, but not as directly related as other paras. Lateral relationship
[347] 8 subsidiary to 1 - another sub process of the overall approach.
[348] none
[349] Relationship - common subject - plasticity of clay. 1 conveys the importance of plastic clay. 8 conveys a technique for restoring plasticity
[350] none

Pottery text: Paragraphs 2 and 3

[351] 2 explains "composition" in 3

[352] I see a relationship. Relationship. is composition of clay, which is described in 2 in much greater detail.

[353] 2 - elaboration on a point referred to at 3 (namely the composition of clays)

[354] There is a relationship Para 3 discusses how to find the clay of 2. And both discuss the composition of the clay (3 says where to go for more info)

[355] 3 is footnote to 2, defining limitations of 2 as information

[356] ref. in 3 to composition of clays - all details given will be in para 2. Takes description of clay into main topic of piece - finding, storing, using clay, particularly in schools

[357] Define suitable pottery 2 <-> 3

[358] Composition of clay: continues the explanation not contained in para 3

[359] Para 2 and 3 sit uncomfortably together because you are expecting from details in para 2 more details about constituents of "best clay" - instead para 3 actually disappoints (doesn't live up to expectations). Readers are left wondering what the connection is between "best clay" (2), and "suitable pottery clays" (3), and what is the degree of balance of mica etc. in clays dug up? And why have schools suddenly been introduced? Different contexts. ...could have come from a different book!

[360] Composition of clay

Pottery text: Paragraphs 2 and 5

[361] Both make reference to the plasticity of clay. Para 2 mentions loss of plasticity, and para 5 expands on how plasticity can be recognised

[362] (a) Creamy state; slip, (b) refers to plasticity of clay needed for normal usage, (c) how to dry, (d) making moulds, why clay is plastic (One way)

[363] 5 is a continuation of 2

[364] Very limited relationship - within the overall context of discussing clay, but nothing specific between the paras

[365] Changes topic of 2 from "reasons for plasticity" to "use of plasticity"

[366] None

[367] A tenuous link. 2 explains why clay can be creamy or plastic that is discussed in 5

[368] Don't find any specific relationship between 2 & 5 except they are both about clay and one is concerned with constituents of clay, and other briefly mentions plasticity - they certainly don't directly follow on one from another.

[369] plasticity - creamy state; drying - expulsion of water; spreading - plasticity; "plastic again" - "right proportion".

[370] There is a relationship between the two on the plasticity of clay

Pottery text: Paragraphs 2 and 7

[371] Unrelated - although they both talk of the same topic - i.e. clay.

[372] There is a relationship. "How to prevent" - i.e. para 7 describes how to avoid the drying out of clay

[373] No relationship

[374] none (except it's about clay)

[375] 7 advises on how to keep clay moist > 2 explains why it should be kept moist: "plasticity when wet".

[376] Only relation implied. Way of storage will help plasticity discussed in 2

[377] No particular relationship here either - para 2 about constituents; para 7 about storing and in context of schools, whereas para 7 not in context of schools and not at same level of interest - para 7: practical advice, a bit pedantic & boring. Paras 4,5,&7 go better together.
[378] moisture - plasticity; water-tight - protecting plasticity - keeping proportions correct. Water at bottom of bin protects and keeps proportions correct.
[379] The only relationship seems that both paras are about clay
[380] No relationship apart from "clay"
[381] none (7->2) since loss of water causes the clay to shrink, storing it in watertight containers is ideal

Pottery text: Paragraphs 2 and 9

[382] The reasons for the activities described in 9 are provided by a 'deep model' description of the nature of the common object (clay) in the first half of 2. One way - 2 explains and justifies 9
[383] In the direction 2->9 only, I read 9 as providing a practical illustration of the feature introduced in 2
[384] 2 is on a different topic to 9
[385] Talking about preservation of clays, plasticity in 9 and in 2 describing the structure of clay which contributes to its plasticity
[386] The paras are on the same subject with one being a "why" (2) and the other being a "how to" (9). It works in one direction - i.e. given para 2 we can go some way towards predicting para 9
[387] No ? relationship. Both paras discuss clay and wetness, but within unrelated contexts
[388] Paragraphs relate on similar subject; 2 is explanation (why) and 9 is explanation (how of physical nature of product
[389] 9 depends on 2, i.e. the properties of clay that lead to the instructions in 9 depend on the ones described in 2. 2 does not depend on 9. Both give some facts about clay
[390] Relationship between scientific explanation of a phenomenon (plasticity of clay) and practical instructions to maintain it

Pottery text: Paragraphs 3 and 4

[391] Continuous - One directional (continues para 4)
[392] <-> Both discuss clay dug locally
[393] 4 explains how to "experiment" with clay dug locally (mentioned in 3)
[394] a relationship exists - between suitable clay, and how it can be found/ used locally. (One direction 3 -> 4, not 4 -> 3)
[395] refers to clays dug locally & gardens, as in para 4
[396] No relationship
[397] subject matter/ clay facts/ composition of clay/ source of clay
[398] There is a strong relationship. They both talk about ways of obtaining the same material for use. The relationship works best from 3 to 4
[399] How to wash clay dug from the garden 3 <>4
[400] Using locally dug clay & preparing it. Continuation of para 3
[401] Good continuation - trail of thought is continuous

Pottery text: Paragraphs 3 and 6

[402] preparation for experiments (Para 3: "...to experiment with clays dug locally, studying results...)
[403] no relationship, other than the general topic of discussing clay/ pottery. One really could connect the two paras either way
[404] Not really
[405] None

[406] No relationship seen
[407] No relationship
[408] Not related
[409] The only relationship is the continued discussion of the preparation. A bit tenuous possibly. A one way relationship
[410] Composition of the clay, goes 6 -> 3, but not vice versa
[411] First para is preparation, second describes types of usable clays - linear relationship

Pottery text: Paragraphs 3 and 8

[412] more details on "experiment" (see E: 3-6)
[413] (same as F: 3-6)
[414] The paras lead on nicely to each other (either way) - I think same can be said above (K1 1-8). Hard to say what the relation is. Maybe can call it an 'introductory' relation - i.e. both give easy to understand information about the clay
[415] 8 advocates the use of different containers for storing different clays, necessary if experiments with different clays are tried out; 8 gives specific information about what is described in 3.
[416] No relationship
[417] No relationship
[418] Not related
[419] No relationship
[420] from 3 to 8, having obtained local clays they need to be stored
[421] No relationship
[422] none

Pottery text: Paragraphs 4 and 5

[423] Paragraph 5 follows on from paragraph 4. i.e. they are both discussing clay in a particular state. The Subject matter of both paragraphs is the same and the discussion in one logically follows on from the discussion in the other
[424] a) refers to gathering own clay, b) soaking to 'cream', c) sieving to purify, d) how to get a sieve. Describes how clay gets into 'cream' state. One way. Provides a context for 5
[425] Expansion : expands on clay's creamy state (One directional) Referential : makes reference to other related work (One directional)
[426] 4 mentions clay in a creamy state, and how to get clay to this state, and 5 mentions what can then be done with clay in this state.
[427] Both refer to the state of the clay to be worked
[428] (4->5) as 4 introduces notion of clay in a creamy state. % then builds on this notion by naming it, and explaining what to do next.
[429] relationship is clay in a creamy state, but 5 anaphorically refers to 4
[430] subject matter/ clay states/ How to get clay into a particular state (4 - creamy - 5 plastic). Effects of moisture
[431] There is a weak relationship. They both talk about a material when it is in a particular state. It only really works from 4 to 5
[432] Both of the paragraphs mention a creamy state of clay. Para 5 seems to follow from para 4
[433] Two methods do follow each other from 4 to 5, yet the last sentence has no connections

Pottery text: Paragraphs 4 and 7

[434] Continuous - One directional (continues para 4)

[435] -> 4 describes preparation of clay, and 7 the correct storage of clay. From external knowledge I get a sequence that 'items' have to be prepared and then stored.
[436] Both describe steps in the preparation and usage of clay. 4 precedes 7. 4 includes the process of adding water and 7 talks about its retention
[437] has a relationship with storage
Both about preparing clay, and has a reverse relationship with para 7 as para 7 is the last stage in preparation
[438] 7 advises how to store clay, 4 advises how to prepare clay (4->7 One way process)
[439] No relationship
[440] subject matter/ clay applications
[441] As in 4:1 (D2: Para 4 - Para 1). There is a weak relationship. As in that section, they both talk about manipulating the same material. It works slightly better from 4 to 7.
[442] Both paras are about bringing clay to a consistency ready for use. The need to keep clay moist is stressed both times.
[443] Treatment of clay, although 7 deals with storage
[444] none
[445] different aspects of clay. 4 gives method of making, 7 gives method of storing

Pottery text: Paragraphs 4 and 9

[446] You are instructed to apply a similar objet (water) to the clay for related reasons (the consistency of the clay)
[447] In both directions 9 <->4, both paras explain the resources needed to prepare and store clay
[448] 4 is on a different topic to 9
[449] no relationship
[450] Once again the relationship deals with the common subject (i.e. clay), and one is a "how to prepare it" and the other is a "how to store it" - a method relationship
[451] No ? relationship (2nd para doesn't follow from the first) - also discusses same objects but within unrelated contexts
[452] Relation in description of equipment and methods used
[453] No relationship (apart from clay). Both describe technique. Both give some facts about clay
[454] Relationship between different stages of a process

Pottery text: Paragraphs 5 and 6

[455] Almost the same as above (Subject A: Para 5 - Para 4). the paragraphs are not describing the same Subject matter, but para 6 is describing the next stage in a process to that described in para 5
[456] Describes further preparation, wedging, and elaborates on wedging - brick and cut. 6 is almost self-contained - except for reference "...condition for use..." relation to 5 is temporal process. The next step to usable clay...
[457] Strong relationship as both explain in detail methods of preparation
[458] Both on preparation of clay for use
[459] No relationship seen
[460] (5->6) 5 describes taking clay from a creamy state to a slab. 6 describes taking this slab and 'wedging' it. Does not work (5 <- 6) as wedging does not result in creamy clay
[461] Operation to prepare the clay, a narrative progression (obviously). Goes 5 -> 6 and 6 -> 5 (an assumption from "A further operation..." is that there was a previous operation
[462] Jump several stages from preparation (forward or backwards)
[463] These two paragraphs discuss the prep. of clay before it can be used. Para 6 follows from para 5

Pottery text: Paragraphs 5 and 8

[464] No relationship

[465] Describes clay reconditioning like the washing preparation in 4. If 8 is taken as part of the manufacturing process, the intro. to colouring can be related to 5 which (it was later discovered) referred to clay making.

[466] Weak relation from 8->5. Relation seems to be on how to use (shape) the clay

[467] 5 gives a partial description of the conditioning process referred to in 8. 5 gives specific practical information about 8

[468] No relationship

[469] 8 refers to different coloured containers in a way that implies that they have already been introduced. 8-5 - Washing clay could result in clay in a creamy state.

[470] No relationship

[471] none

[472] Relationship - 5 describes a stage in washing clay; 8 describes how washing can be used to restore old clay.

[473] none

[474] no relationship

Pottery text: Paragraphs 6 and 7

[475] two steps in prep. and use - 6 precedes 7

[476] Both about preparing clay, and has a reverse relationship with para 7 as para 7 is the last stage in preparation

[477] Relationship as furthers preparation

[478] None

[479] 7 describes how to store clay - 6 describes how to wedge clay (6->7 One way process)

[480] The relationship between the paragraphs is how to create and maintain the correct consistency of the clay. Para 6 talks about wedging the clay and obtaining the correct consistency which leads the reader to anticipate what to do once this consistency has been reached, i.e. how to shape the clay, or how to maintain this consistency, so that it doesn't dry out, as explained in para 7. The relationship works in this direction only

[481] A refinement on bringing the clay into use, therefore para 6 is subsequent to para 7

[482] No obvious relation, a change of subject makes them disjointed - they could be a progression, but not necessarily

[483] none

[484] From use to storage. What to do with prepared clay if you're not going to use it

Pottery text: Paragraphs 6 and 9

[485] 6 describes a precondition activity (wedging) of the main activity (working with clay) and the state (workable/ evenly consistent) while 9 describes a precondition activity (keeping it moist) for maintaining the state (workable) when the main activity is suspended/ interrupted.

[486] 6 -> 9 I read 6 as stating a precondition; 9 as stating a post condition of working with the material

[487] 6 is on a different topic to 9

[488] Both paras discuss the best condition that the clay should be in to make it perfectly workable. i.e. 9 discusses preservation of plasticity of half completed work, and 6 discusses how to achieve the best texture and plasticity of clay before using it

[489] The relationship this time method - i.e. method of further preparation (para 6) and method of storage (para 9)
[490] No relationship at all beyond discussion of a common object (clay)
[491] method description
[492] 9 comes after 6 in the sense that 6 always has to be done before 9 would be. 6 can't come after 9. They both describe a technique
[493] Relationship between different stages of a process

Pottery text: Paragraphs 7 and 8

[494] Yes, definite relation about how to store the clay, and what types of containers to use. (<->
[495] 7 describes the containers referred to in 8. 7 descriptively elaborates on 8.
[496] 8 is an elaboration of the storage requirements described in 7
[497] Both about storing of clay
[498] Containers for keeping the clay in The clay needs to be kept wet (7) although can be rescued (8). Works both ways.
[499] Closely related under storing clay - both mention containers and water; 7 is general, 8 is specialised: "different coloured clays" - "old clay which has gone hard"
[500] the relation goes both ways. Given the different colour clays and the appropriate tins, the ref. to 7 for the methods of storage of these clays and vice versa
[501] Relationship - clay storage (7->8)
[502] 8 is subsequent to 7 in that it goes into the subject matter of 7 in greater detail.
[503] Both paras discuss containers
[504] Only about containers
[505] to recondition clay soaking in water is used but the fact that it's covered is not intuitive

Pottery text: Paragraphs 8 and 9

[506] 8 provides elaboration, specialisation and extension (reconditioning 0 of the activities in 9 (if the containers are biscuit tins, not buckets??)
[507] 9 -> 8 i read 8 as a continuation and expansion upon the topic of 9
[508] 8 is on a different topic to 9
[509] Both paras refer to the use of containers for storing and preserving the clay. 8 suggests the use of containers and 9 goes on to expiate on this
[510] Both paras talk about the storage of clay - 9 going into somewhat more detail
[511] No ? relationship beyond discussion of the same object within unrelated contexts
[512] Again, method and equipment, relation in subject matter
[513] No relation (apart from clay)
They both describe a technique
[514] no relationship

4. APPENDIX 4: EXPERIMENT 1.2 INSTRUCTIONS

This experiment will take approximately one and a half hours to complete.

You have been given a set of *relationship descriptions.* and two pages of text with numbered paragraphs on them (These are the 'Travel' and 'Pottery' texts). Each of these *relationship descriptions.* describes how two paragraphs from one of the pieces of text is related.

Your task is to sort the *relationship descriptions.* into a number of categories of self-similar relationships, and to describe what those categories are. The categories of relationships should be different from each other, but may overlap or include one another. 'Similar' here means that the *relationships* that are described are similar. Note that you should be careful not to make your similarity judgements on the basis of similarity of subject matter.

You may sort them into as many categories as you wish. You can do this by putting each category into a separate envelope or pile or whatever, just so long as they can be returned to me along with their descriptions as separate categories.

First, read through the 'Pottery' text and the 'Travel' text.
Go through the stack of *relationship descriptions*, one by one.
With each one, either:
(i) Put it into one of your categories of relationship if you think it describes a relationship similar to those in that category. (If more than one category seems to apply, don't worry, put it into the one that applies most strongly. Also, don't worry if you seem to be putting a lot into one category.)
(ii) Start a new category of relationships with it.
(iii) If you can't decide or if its meaning is unclear, leave it to one side until the end.

As you go through the set of *relationship descriptions*, sorting them into categories, you will be forming ideas as to what the categories are. When you have finished, describe these categories, giving a full description of the meaning and scope of each category (say, a few sentences on each). It would be best if you write these descriptions on separate pieces of paper and give them back to me with each category of *relationship descriptions.*

When you have gone through all the *relationship descriptions,* sorted them all into categories, and described the categories, go through each of the categories in turn, verifying that each of the *relationship descriptions* you have assigned to that category belongs there, and more importantly, that the category description is correct and accurate.

Thank you very much for sparing the time to do this experiment.

Henry Bloomfield

5. APPENDIX 5: EXPERIMENT 1.2 RESULTS

This section shows the descriptions the six subjects in Experiment 1.2 (described in chapter 4) gave to the categories they made of the responses from the previous study. Each subject is given a letter (A to F), and each of their categories is given a number.

A.1 The two pieces of text refer to the same thing, they are on the same topic, they mention the same thing

A.2 The two paragraphs talk about different things, but which are covered by the same general thing

A.3 Don't know

A.4 There is a small shift of topic - The main topic remains the same, but is dealt with in a different context/ for different reasons/ in a different way

A.5 One piece of text explains something in the other, answers "Why?" questions, describes the reasons for something in the other piece of text.

A.6 One piece of text reiterates what is in the other, but more fully. There is an expansion or elaboration

A.7 One piece of text introduces the other

A.8 One piece of text gives detail on something from the other. There is a refinement, or one piece of text may be much more specific than the other.

A.9 One piece of text gives background information relevant to the other.

A.10 Continue - There is a sequence of steps in some process or narrative which carries over from one piece of text to the other; a natural progression, maybe a flow of time as well.

A.11 One paragraph describes something from the other or something relevant to the other.

A.12 Advice or instructive information is given in one piece of text about the information in the other piece - "How to..." information as well.

A.13 An illustration or example/ analogy of something in one piece of text is given in the other

B.1 Both paragraphs refer to the same general subject

B.2 Unknown

B.3 Paragraphs discuss different aspects of the same subject

B.4 Expansion/ Elaboration - One paragraph explains a concept mentioned in the other (It may not be the same subject of the other paragraph)

B.5 Specialisation - One paragraph is introductory on a subject, the second specialises

B.6 Continuation - One paragraph naturally follows the other

B.7 The structure of paragraphs and intended function is the same (regardless of context or the content of the paragraphs)

B.8 Advice - One paragraph gives practical advice on some subject in the other

C.1 Could be subtype of [C.7], only the subject is not identified. We know that some common context should be there and reference is made to that, but we do not know the subject or content about one or both of the paragraphs. Same subject, but not specific to these two paragraphs.

C.2 No connection at all

C.3 Don't know

C.4 They are related by subject/content. The relationship is identified by describing some aspect of the content in each of the paragraphs related. The relationship refers to commonality of

theme, different aspects of it. Some subject relationship [C.1] descriptions would also be classified as "verbose": they are just too long to be meaningful.

C.5 It could be a subtype of [C.6], it refers to contingent, strongly directed relationships only. One paragraph is like a follow-up dependent on the other. It is different from 'theme' types, because the definition of the relationship does not mention the actual theme in question.

C.6 The kind of the relationship is identified without reference to the subject/content at all. The relationship talks about the 'type' of knowledge/ information that is found in the text without reference to its content.

C.7 It could be like only reference is made only to the common characteristics of the paragraphs, that is without describing individual aspects of the paragraphs. So the description says something like, they both do this, they both talk about this, but we know nothing in particular about one or the other. Common context without reference to the individual aspects covered. Just that they refer to the same stuff. In the common subject [C.7], I have classified relations of the sort "they both refer to..." in cases where it seems that this is their shared topic rather than an off chance reference. This distinction is though a bit hard to make from reading a relationship definition, though the cases seem sufficiently distinct to me. At the same time I do not assume that [C.4] and [C.7] are disjoint. Whenever something mentions individual characteristics of one or both paragraphs I immediately put it in [C.4], even though it might in fact also mention the common topic. (it doesn't though describe the type of relationship in which case I would put it in [C.9]). *[Reference is only made to the common subject matter of the two paragraphs, not how each paragraph deals with it.]*

C.8 Common reference, but nothing else. It is disjoint from [C.7] and [C.1]. The relationship refers to the content, not the subject. There is no other relationship mentioned but a common bit of content, common reference in the content. There is a common element. *[A thing common to both paras is reported - this isn't necessarily the main topic of either paragraph]*

C.9 A description of the type of relationship is offered along with some information on the content. Could be an intersection of any of {[C.6], [C.5]} X {[C.4], [C.7], [C.1], [C.8]} but for convenience I merged them all together. They are related by type, but also by some connection of the theme.

C.10 Another further attribute I think in retrospect would have been used as a classification criterion within [C.6], and [C.4] (only those because they are the big ones) would be reference to another relationship noted (before?) e.g. [C.6] & [C.5] like [C.7] & [C.8].

D.1 Same subject (General). Includes very general "weak" and "strong" relationships - could be separated into two.

D.2 No relationship

D.3 Didn't understand/ relationship not stated

D.4 Same subject (different aspects) i.e. disjoint, although in the context of the overall text, otherwise no relationship.

D.5 Expand, elaborate, enlarge, amplify

D.6 Same subject - one is a subset of the other (General -> specific)

D.7 Same subject; Directional, progression. Continuation, can be temporal.

D.8 Same function. e.g. both give advice, facts, both describe/ explain, although don't have to be same subject.

D.9 Describe - one describes the other, or describes something in the other

D.10 Explain, elucidate - why, how, one explains the other

D.11 Contrast, compare - one contrasts, compares with the other

D.12 Contradict

E.1 Continuity of subject (In sets, 'continuity' is a subset of 'specific content' [E.5])

E.2 General content - weak subject overlap

E.3 No relation

E.4 Amplification -> Continuity - further explanation of subject (- this implies continuity of subject) (In sets, 'amplification' is a subset of 'continuity' [E.1])

E.5 Specific content - strong subject overlap

E.6 Weak relation - possible subject overlap

F.1 "Complements" - the two paragraphs present observations upon the one topic (a generic relation!) without being specific enough to categorise as elaboration, etc.

F.2 None - no clear relation - due to inability to understand material or to categorise description in any way

F.3 'Not used' descriptions

F.4 Elaborates - One paragraph provides expansion of a point raised in the other, providing the detail necessary to make a point or explain a concept. 'Generalises' can be regarded as the opposite relation.

F.5 Enablement. The first paragraph describes the actions/ conditions which enable the actions described in the second paragraph

F.6 Causal - (Motivational) One paragraph describes a situation which causes the situation or motivates the actions described in the other.

F.7 Sequential - The paragraphs described are related temporally, one precedes or succeeds the other

F.8 contrast The paragraphs present contradicting statements, or present opposed views

F.9 Exemplify One paragraph provides an example to illustrate a concept introduced by another

6. APPENDIX 6: EXPERIMENT 2.1 INSTRUCTIONS

Pre-Experiment Questionnaire

1. Are you a student? Yes No (Circle one answer)

   If you answered, "Yes", put your course and year below:

   .....

2. In the book "Human Computer Interaction" by Peter Johnson, have you read chapter 2, "An Introduction to Human Memory"?

   Yes No (Circle one answer)

3. Are you familiar with the concept of hypertext?

   Yes No (Circle one answer)

4. Have you ever used a hypertext system before?

   Yes No (Circle one answer)

5. Do you know how to repair a bicycle puncture?

   Yes No (Circle one answer)

Introduction

In this experiment, you will be asked to answer 4 questions about human memory, with the help of a hypertext system containing information about human memory. It does not matter if you do not know about hypertext or about human memory before doing the experiment.

Before doing the experiment, please answer the questions below, to the best of your ability.

The questions

1. What is the distinction between short term memory and working memory?

.....

.....

.....

.....

2. How is memory searched - serial or parallel?

.....

.....

.....

.....

3. What happens when people are allowed to recall things in any order?

.....

.....

.....

.....

4. When the items to be recalled are well-known to the subject, how does this affect their recall?

.....

.....

.....

.....

Naming the relationships

Pieces of information in the hypertext are linked together by relationships. Below, twelve relationship types are described. Each relationship type has a number of descriptions. Your task is to read and understand the descriptions, and then to summarise them in one or two words that will remind you (when using the hypertext) what the meaning of the relationship was.

Relationship 1

- The two pieces of text refer to the same thing, they are on the same topic, they mention the same thing
- Both paragraphs refer to the same general subject
- We know that some common context should be there and reference is made to that, but we do not know the subject or content about one or both of the paragraphs. Same subject, but not specific to these two paragraphs. *[Reference is made to common subject matter, a general subject matter]*
- Common reference, but nothing else. The relationship refers to the content, not the subject. There is no other relationship mentioned but a common bit of content, common reference in the content. There is a common element. *[A thing common to both paras is reported - this isn't necessarily the main topic of either paragraph]*
- Same subject (General). Includes very general "weak" and "strong" relationships - could be separated into two.
- Continuity of subject
- "Complements" - the two paragraphs present observations upon the one topic (a generic relation!) without being specific enough to categorise as elaboration.

Your summary of this relationship: .....

Relationship 2

- The two paragraphs talk about different things, but which are covered by the same general thing
- Specific content - strong subject overlap

Your summary of this relationship:.....

Relationship 3

- One paragraph describes something from the other or something relevant to the other.
- Describe - one describes the other, or describes something in the other

Your summary of this relationship:.....

Relationship 4

- There is a small shift of topic - The main topic remains the same, but is dealt with in a different context/ for different reasons/ in a different way
- Paragraphs discuss different aspects of the same subject
- They are related by subject/content. The relationship is identified by describing some aspect of the content in each of the paragraphs related. The relationship refers to commonality of theme, different aspects of it. *[common subject/ theme reported in both paras, but dealt with in different ways in each paragraph]*
- Same subject (different aspects) i.e. disjoint, although in the context of the overall text, otherwise no relationship.

Your summary of this relationship:.....

Relationship 5

- An illustration or example/ analogy of something in one piece of text is given in the other
- Exemplify: One paragraph provides an example to illustrate a concept introduced by another

Your summary of this relationship: .....

Relationship 6

- The structure of paragraphs and intended function is the same (regardless of context or the content of the paragraphs)
- The kind of the relationship is identified without reference to the subject/content at all. The relationship talks about the 'type' of knowledge/ information that is found in the text without reference to its content *[Some relationship identified without the paragraphs' subject matter being identified]*
- Same function. e.g. both give advice, facts, both describe/ explain, although don't have to be same subject.

Your summary of this relationship: .....

Relationship 7

- Continue - There is a sequence of steps in some process or narrative which carries over from one piece of text to the other; a natural progression, maybe a flow of time as well.
- Continuation - One paragraph naturally follows the other
- Same subject; Directional, progression. Continuation, can be temporal.
- Sequential - The paragraphs described are related temporally, one precedes or succeeds the other

Your summary of this relationship: .....

Relationship 8

- One piece of text explains something in the other, answers "Why?" questions, describes the reasons for something aid in the other piece of text.
- Explain, elucidate - why, how, one explains the other

Your summary of this relationship:.....

Relationship 9

- One piece of text gives detail on something from the other. There is a refinement, or one piece of text may be much more specific than the other.
- Specialisation - One paragraph is introductory on a subject, the second specialises

Your summary of this relationship:.....

Relationship 10

- One piece of text reiterates what is in the other, but more fully. There is an expansion or elaboration
- Expansion/ Elaboration - One paragraph explains a concept mentioned in the other (It may not be the same subject of the other paragraph)
- A description of the type of relationship is offered along with some information on the content. They are related by type, but also by some connection of the theme. *[The type of relationship and the subject matter are reported]*
- Expand, elaborate, enlarge, amplify
- Elaborates - One paragraph provides expansion of a point raised in the other, providing the detail necessary to make a point or explain a concept. 'Generalises' can be regarded as the opposite relation.

Your summary of this relationship:.....

Relationship 11

- Contrast, compare - one contrasts, compares with the other
- Contrast: The paragraphs present contradicting statements, or present opposed views

Your summary of this relationship: .....

Relationship 12

- One piece of text gives background information relevant to the other.
- General content - weak subject overlap

Your summary of this relationship: .....

When you have named all the relationships, ask for the hypertext to be set up with these relationship types. You may then go on to the hypertext part of the experiment.

Answering the questions with the hypertext

Using the hypertext: When you are presented with the screen with the words "Chapter 2: An Introduction to Human Memory" on it, click the mouse on the button "Click here", to proceed to the hypertext. Then, after a short delay, you will be presented with the hypertext.

The screen will show a paragraph of text, and below it, extracts from the text, with hypertext links that apply to that extract in the context of the text. You can follow the links by clicking on them.

Also, there are at the bottom of the screen, buttons that will take you to the 'Next' or 'Previous' pieces of text in the paper version of the text that the hypertext is based on. There are also two buttons that will take you to a representation of the text organised as a hierarchy, and there is a button that will take you to the most recently visited piece of text ('Back').

The buttons along the top of the screen named "Fig. x" will display the figures referred to in the text.

IMPORTANT: If there is anything you do not understand about using the hypertext, please ask.

What you are asked to do is this: Using the hypertext, answer the questions given here. When doing this, it is important that you only answer one question at a time.

1. What is the distinction between short term memory and working memory?

.....

.....

.....

.....

.....

2. How is memory searched - serial or parallel?

.....

.....

.....

.....

.....

3. What happens when people are allowed to recall things in any order?

.....

.....

.....

.....

.....

4. When the items to be recalled are well-known to the subject, how does this affect their recall?

.....

.....

.....

.....

.....

Testing Expectation

The final part of the experiment asks you to determine either:

1. Which of 4 paragraphs you expected to follow a certain combination of a paragraph of text and a hypertext link. These 4 paragraphs will be presented to you one at a time, with the combination of the single paragraph and link presented in between each test paragraph. You will, with each presented paragraph, be asked a Yes/ No question as to whether it was what you expected to follow the paragraph and link.
2. Which of 4 paragraphs you feel to be most strongly, or most relevantly linked to another paragraph, in particular to a certain underlined phrase in that paragraph.

Thank you very much for sparing the time to do this experiment.

7. APPENDIX 7: ANOVA SUMMARIES

7.1. ANOVA summary for Expt. 2.1: Rn/n

	Qu. 1	Qu. 2	Qu. 3	Qu. 4
Tr.1	0.	0.	0.	0.
	0.052	0.088	0.25	0.225
	0.5	0.727	0.875	0.643
	0.35	0.286	0.348	0.231
	0.284	0.214	0.333	0.286
	0.292	0.389	0.151	0.429
	0.025	0.083	0.075	0.
	0.429	0.667	0.094	0.037
Tr.2	0.176	0.136	0.093	0.1
	0.097	0.222	0.118	0.294
	0.229	0.	0.3	0.167
	0.746	0.154	0.	0.25
	0.08	0.131	0.222	0.
	0.	0.	0.	0.
	0.421	0.875	0.286	0.077
	0.389	0.5	0.25	0.5
Tr.3	0.4	0.5	1.	0.333
	0.152	0.188	0.098	0.163
	0.476	0.676	0.682	0.16
	0.111	0.636	0.467	0.467
	0.385	0.647	0.727	0.75
	0.417	1.	0.9	0.612
	0.697	0.857	0.867	0.591
	0.545	0.583	0.808	0.571
Tr.4	0.341	0.294	0.429	0.417
	0.	0.	0.	0.
	0.667	0.813	0.2	0.07
	0.455	0.318	0.444	0.273
	0.583	0.889	0.706	0.333
	0.333	0.417	0.2	0.25
	0.231	0.083	0.208	0.08
	0.474	0.263	0.31	0.462

Anova: Two-Factor With Replication

Summary

	Qu. 1	*Qu. 2*	*Qu. 3*	*Qu. 4*	*Total*
Tr. 1					
Count	8.	8.	8.	8.	32.
Sum	1.931	2.454	2.126	1.85	8.361
Average	0.241	0.307	0.266	0.231	1.045
Variance	0.037	0.073	0.076	0.051	0.237
Tr. 2					
Count	8.	8.	8.	8.	32.
Sum	2.138	2.019	1.269	1.388	6.813
Average	0.267	0.252	0.159	0.173	0.852
Variance	0.059	0.088	0.015	0.029	0.191
Tr. 3					
Count	8.	8.	8.	8.	32.
Sum	3.183	5.087	5.548	3.647	17.465
Average	0.398	0.636	0.693	0.456	2.183
Variance	0.037	0.058	0.084	0.047	0.226
Tr. 4					
Count	8.	8.	8.	8.	32.
Sum	3.083	3.077	2.498	1.884	10.542
Average	0.385	0.385	0.312	0.236	1.318
Variance	0.044	0.101	0.046	0.029	0.219
Total					
Count	32.	32.	32.	32.	
Sum	10.334	12.637	11.44	8.769	
Average	1.292	1.58	1.43	1.096	
Variance	0.177	0.32	0.221	0.156	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	2.073	3.	0.691	12.655	0.	2.686
Column	0.254	3.	0.085	1.55	0.206	2.686
Interaction	0.447	9.	0.05	0.909	0.52	1.964
Within	6.115	112.	0.055			
Total	8.889	127.				

This shows the ANOVA summary for Rn/n, the proportion of Relational links used by the subjects (Rn) to the total number of links used by the subject (n). On the left are the values obtained by the subjects in the four treatments (Tr.1 ... Tr.4) for the four questions (Qu. 1 ...Qu. 4), and on the right, a summary of the ANOVA showing the means and variances for the four treatments over the four questions (trials). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the treatments (Sample), for the questions (Column), and for the interaction between these (Interaction).

Only the differences between the 'Sample' means were significant, as only ($F_{Sample} > Fcrit_{Sample}$).

7.2. ANOVA summary for Expt. 2.1: n

	Qu. 1	Qu. 2	Qu. 3	Qu. 4
Tr.1	21.	10.	4.	4.
	97.	34.	12.	40.
	34.	11.	8.	42.
	20.	14.	23.	13.
	67.	14.	6.	7.
	24.	18.	73.	98.
	79.	12.	40.	9.
	42.	18.	85.	27.
Tr.2	17.	22.	43.	20.
	31.	9.	17.	17.
	35.	1.	10.	30.
	63.	26.	3.	4.
	25.	61.	9.	5.
	3.	4.	3.	8.
	19.	8.	14.	13.
	18.	10.	4.	6.
Tr.3	5.	16.	8.	6.
	66.	32.	41.	43.
	21.	37.	22.	25.
	36.	11.	15.	15.
	13.	34.	11.	16.
	12.	7.	10.	49.
	33.	14.	15.	22.
	11.	12.	26.	7.
Tr.4	44.	17.	7.	12.
	5.	3.	12.	4.
	12.	16.	10.	43.
	33.	22.	9.	11.
	12.	9.	34.	27.
	9.	12.	25.	4.
	13.	24.	24.	25.
	38.	38.	29.	13.

Anova: Two-Factor With Replication

Summary

	Qu. 1	*Qu. 2*	*Qu. 3*	*Qu. 4*	*Total*
Tr.1					
Count	8.	8.	8.	8.	32.
Sum	384.	131.	251.	240.	1006.
Average	48.	16.375	31.375	30.	125.75
Variance	863.429	59.411	1009.696	973.143	2905.679
Tr.2					
Count	8.	8.	8.	8.	32.
Sum	211.	141.	103.	103.	558.
Average	26.375	17.625	12.875	12.875	69.75
Variance	313.982	379.696	174.696	81.839	950.214
Tr.3					
Count	8.	8.	8.	8.	32.
Sum	197.	163.	148.	183.	691.
Average	24.625	20.375	18.5	22.875	86.375
Variance	398.554	141.982	119.714	248.411	908.661
Tr.4					
Count	8.	8.	8.	8.	32.
Sum	166.	141.	150.	139.	596.
Average	20.75	17.625	18.75	17.375	74.5
Variance	226.786	113.982	108.5	179.125	628.393
Total					
Count	32.	32.	32.	32.	
Sum	958.	576.	652.	665.	
Average	119.75	72.	81.5	83.125	
Variance	1802.75	695.071	1412.607	1482.518	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	3876.461	3.	1292.154	3.834	0.012	2.686
Column	2650.586	3.	883.529	2.621	0.054	2.686
Interaction	2579.758	9.	286.64	0.85	0.572	1.964
Within	37750.625	112.	337.059			
Total	46857.43	127.				

This shows the ANOVA summary for n, the total number of links used by the subject.

On the left are the values obtained by the subjects in the four treatments (Tr.1 ... Tr.4) for the four questions (Qu. 1 ...Qu. 4), and on the right, a summary of the ANOVA showing the means and variances for the four treatments over the four questions (trials). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the treatments (Sample), for the questions (Column), and for the interaction between these (Interaction).

Only the differences between the 'Sample' means were significant, as only ($F_{Sample} > Fcrit_{Sample}$).

7.3. ANOVA summary for Expt. 2.1: Rn

	Qu. 1	Qu. 2	Qu. 3	Qu. 4
Tr.1	0.	0.	0.	0.
	5.	3.	3.	9.
	17.	8.	7.	27.
	7.	4.	8.	3.
	19.	3.	2.	2.
	7.	7.	11.	42.
	2.	1.	3.	0.
	18.	12.	8.	1.
Tr.2	3.	3.	4.	2.
	3.	2.	2.	5.
	8.	0.	3.	5.
	47.	4.	0.	1.
	2.	8.	2.	0.
	0.	0.	0.	0.
	8.	7.	4.	1.
	7.	5.	1.	3.
Tr.3	2.	8.	8.	2.
	10.	6.	4.	7.
	10.	25.	15.	4.
	4.	7.	7.	7.
	5.	22.	8.	12.
	5.	7.	9.	30.
	23.	12.	13.	13.
	6.	7.	21.	4.
Tr.4	15.	5.	3.	5.
	0.	0.	0.	0.
	8.	13.	2.	3.
	15.	7.	4.	3.
	7.	8.	24.	9.
	3.	5.	5.	1.
	3.	2.	5.	2.
	18.	10.	9.	6.

Anova: Two-Factor With Replication

Summary

	Qu. 1	*Qu. 2*	*Qu. 3*	*Qu. 4*	*Total*
Tr.1					
Count	8.	8.	8.	8.	32.
Sum	75.	38.	42.	84.	239.
Average	9.375	4.75	5.25	10.5	29.875
Variance	56.839	15.929	14.214	243.714	330.696
Tr.2					
Count	8.	8.	8.	8.	32.
Sum	78.	29.	16.	17.	140.
Average	9.75	3.625	2.	2.125	17.5
Variance	235.357	8.839	2.571	4.125	250.893
Tr.3					
Count	8.	8.	8.	8.	32.
Sum	65.	94.	85.	79.	323.
Average	8.125	11.75	10.625	9.875	40.375
Variance	43.839	56.5	29.411	80.982	210.732
Tr.4					
Count	8.	8.	8.	8.	32.
Sum	69.	50.	52.	29.	200.
Average	8.625	6.25	6.5	3.625	25.
Variance	44.268	17.643	56.857	8.554	127.321
Total					
Count	32.	32.	32.	32.	
Sum	287.	211.	195.	209.	
Average	35.875	26.375	24.375	26.125	
Variance	380.304	98.911	103.054	337.375	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	551.531	3.	183.844	3.199	0.026	2.686
Column	162.344	3.	54.115	0.941	0.423	2.686
Interaction	516.344	9.	57.372	0.998	0.446	1.964
Within	6437.5	112.	57.478			
Total	7667.719	127.				

This shows the ANOVA summary for Rn, the number of Relational links used by the subject.

On the left are the values obtained by the subjects in the four treatments (Tr.1 ... Tr.4) for the four questions (Qu. 1 ...Qu. 4), and on the right, a summary of the ANOVA showing the means and variances for the four treatments over the four questions (trials). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the treatments (Sample), for the questions (Column), and for the interaction between these (Interaction).

Only the differences between the 'Sample' means were significant, as only ($F_{Sample} > Fcrit_{Sample}$).

7.4. ANOVA summary for Expt. 2.1: Nn

	Qu. 1	Qu. 2	Qu. 3	Qu. 4
Tr.1	21.	10.	4.	4.
	92.	31.	9.	31.
	17.	3.	1.	15.
	13.	10.	15.	10.
	48.	11.	4.	5.
	17.	11.	62.	56.
	77.	11.	37.	9.
	24.	6.	77.	26.
Tr.2	14.	19.	39.	18.
	28.	7.	15.	12.
	27.	1.	7.	25.
	16.	22.	3.	3.
	23.	53.	7.	5.
	3.	4.	3.	8.
	11.	1.	10.	12.
	11.	5.	3.	3.
Tr.3	3.	8.	0.	4.
	56.	26.	37.	36.
	11.	12.	7.	21.
	32.	4.	8.	8.
	8.	12.	3.	4.
	7.	0.	1.	19.
	10.	2.	2.	9.
	5.	5.	5.	3.
Tr.4	29.	12.	4.	7.
	5.	3.	12.	4.
	4.	3.	8.	40.
	18.	15.	5.	8.
	5.	1.	10.	18.
	6.	7.	20.	3.
	10.	22.	19.	23.
	20.	28.	20.	7.

Anova: Two-Factor With Replication

Summary

	Qu. 1	*Qu. 2*	*Qu. 3*	*Qu. 4*	*Total*
Tr.1					
Count	8.	8.	8.	8.	32.
Sum	309.	93.	209.	156.	767.
Average	38.625	11.625	26.125	19.5	95.875
Variance	932.268	69.696	860.125	311.143	2173.232
Tr.2					
Count	8.	8.	8.	8.	32.
Sum	133.	112.	87.	86.	418.
Average	16.625	14.	10.875	10.75	52.25
Variance	76.268	311.143	146.411	59.929	593.75
Tr.3					
Count	8.	8.	8.	8.	32.
Sum	132.	69.	63.	104.	368.
Average	16.5	8.625	7.875	13.	46.
Variance	335.714	68.268	146.411	133.143	683.536
Tr.4					
Count	8.	8.	8.	8.	32.
Sum	97.	91.	98.	110.	396.
Average	12.125	11.375	12.25	13.75	49.5
Variance	84.411	95.696	44.214	161.071	385.393
Total					
Count	32.	32.	32.	32.	
Sum	671.	365.	457.	456.	
Average	83.875	45.625	57.125	57.	
Variance	1428.661	544.804	1197.161	665.286	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	3300.086	3.	1100.029	4.588	0.005	2.686
Column	1581.273	3.	527.091	2.199	0.092	2.686
Interaction	2155.695	9.	239.522	0.999	0.445	1.964
Within	26851.375	112.	239.744			
Total	33888.43	127.				

This shows the ANOVA summary for Nn, the number of Navigational links used by the subject.

On the left are the values obtained by the subjects in the four treatments (Tr.1 ... Tr.4) for the four questions (Qu. 1 ...Qu. 4), and on the right, a summary of the ANOVA showing the means and variances for the four treatments over the four questions (trials). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the treatments (Sample), for the questions (Column), and for the interaction between these (Interaction).

Only the differences between the 'Sample' means were significant, as only ($F_{Sample} > Fcrit_{Sample}$).

7.5. ANOVA summary for Expt. 2.1: (Postscore-Prescore)

	Qu. 1	Qu. 2	Qu. 3	Qu. 4
Tr.1	0.	2.	1.	0.
	0.	0.	2.	0.
	4.	3.	-1.	2.
	3.	3.	1.	1.
	0.	3.	0.	2.
	0.	0.	2.	2.
	4.	4.	3.	2.
	0.	5.	3.	3.
Tr.2	3.	2.	-1.	-1.
	0.	4.	1.	0.
	2.	2.	1.	1.
	4.	3.	1.	2.
	2.	2.	1.	0.
	0.	2.	-1.	2.
	2.	3.	1.	3.
	2.	1.	1.	0.
Tr.3	0.	2.	2.	1.
	2.	5.	2.	4.
	5.	2.	1.	3.
	4.	4.	4.	3.
	3.	0.	1.	1.
	4.	2.	1.	2.
	2.	2.	1.	2.
	2.	4.	1.	3.
Tr.4	1.	2.	3.	2.
	4.	3.	-1.	1.
	2.	2.	1.	1.
	5.	3.	3.	2.
	0.	3.	2.	2.
	3.	2.	3.	1.
	2.	2.	3.	3.
	2.	5.	3.	2.

Anova: Two-Factor With Replication

Summary

	Qu. 1	*Qu. 2*	*Qu. 3*	*Qu. 4*	*Total*
Tr.1					
Count	8.	8.	8.	8.	32.
Sum	11.	20.	11.	12.	54.
Average	1.375	2.5	1.375	1.5	6.75
Variance	3.696	3.143	1.982	1.143	9.964
Tr.2					
Count	8.	8.	8.	8.	32.
Sum	15.	19.	4.	7.	45.
Average	1.875	2.375	0.5	0.875	5.625
Variance	1.839	0.839	0.857	1.839	5.375
Tr.3					
Count	8.	8.	8.	8.	32.
Sum	22.	21.	13.	19.	75.
Average	2.75	2.625	1.625	2.375	9.375
Variance	2.5	2.554	1.125	1.125	7.304
Tr.4					
Count	8.	8.	8.	8.	32.
Sum	19.	22.	17.	14.	72.
Average	2.375	2.75	2.125	1.75	9.
Variance	2.554	1.071	2.125	0.5	6.25
Total					
Count	32.	32.	32.	32.	
Sum	67.	82.	45.	52.	
Average	8.375	10.25	5.625	6.5	
Variance	10.589	7.607	6.089	4.607	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	19.406	3.	6.469	3.582	0.016	2.686
Column	25.406	3.	8.469	4.69	0.004	2.686
Interaction	10.156	9.	1.128	0.625	0.774	1.964
Within	202.25	112.	1.806			
Total	257.219	127.				

This shows the ANOVA summary for (Postscore-Prescore), the improvement in the score of the subject from answering the questions before and after using the hypertext.

On the left are the values obtained by the subjects in the four treatments (Tr.1 ... Tr.4) for the four questions (Qu. 1 ...Qu. 4), and on the right, a summary of the ANOVA showing the means and variances for the four treatments over the four questions (trials). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the treatments (Sample), for the questions (Column), and for the interaction between these (Interaction).

The differences between both the 'Sample' and 'Column' means were significant, as (F_{Sample} > $Fcrit_{Sample}$) and (F_{Column} > $Fcrit_{Column}$).

7.6. ANOVA summary for Expt. 2.1: t

	Qu. 1	Qu. 2	Qu. 3	Qu. 4
Tr.1	600.	302.	111.	302.
	1206.	302.	107.	329.
	553.	193.	164.	419.
	887.	365.	367.	196.
	1085.	226.	117.	187.
	329.	332.	590.	973.
	1034.	140.	456.	341.
	978.	608.	1149.	262.
Tr.2	570.	549.	519.	447.
	626.	329.	266.	317.
	946.	31.	234.	326.
	879.	240.	13.	44.
	351.	448.	179.	54.
	21.	17.	16.	38.
	756.	348.	332.	218.
	509.	192.	94.	89.
Tr.3	255.	335.	230.	85.
	996.	463.	489.	354.
	542.	580.	443.	391.
	554.	316.	454.	241.
	703.	970.	236.	395.
	176.	136.	225.	375.
	1061.	500.	400.	440.
	364.	302.	253.	71.
Tr.4	726.	188.	98.	183.
	354.	33.	233.	40.
	460.	555.	368.	613.
	1317.	420.	314.	309.
	273.	262.	719.	398.
	195.	212.	192.	61.
	319.	365.	491.	177.
	1159.	816.	462.	288.

Anova: Two-Factor With Replication

Summary

	Qu. 1	*Qu. 2*	*Qu. 3*	*Qu. 4*	*Total*
		Tr.1			
Count	8.	8.	8.	8.	32.
Sum	6672.	2468.	3061.	3009.	15210.
Average	834.	308.5	382.63	376.13	1901.25
Variance	93381.71	20295.43	129152.27	64040.7	306870.11
		Tr.2			
Count	8.	8.	8.	8.	32.
Sum	4658.	2154.	1653.	1533.	9998.
Average	582.25	269.25	206.63	191.63	1249.75
Variance	89495.93	35314.21	29263.98	24936.27	179010.39
		Tr.3			
Count	8.	8.	8.	8.	32.
Sum	4651.	3602.	2730.	2352.	13335.
Average	581.38	450.25	341.25	294.	1666.88
Variance	105306.84	63092.79	13300.5	21043.71	202743.84
		Tr.4			
Count	8.	8.	8.	8.	32.
Sum	4803.	2851.	2877.	2069.	12600.
Average	600.38	356.38	359.63	258.63	1575.
Variance	181782.27	59643.13	38803.13	35377.41	315605.93
	Total				
Count	32.	32.	32.	32.	
Sum	20784.	11075.	10321.	8963.	
Average	2598.	1384.38	1290.13	1120.38	
Variance	469966.75	178345.55	210519.88	145398.09	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	4.37E+05	3.	145674.13	2.32	0.08	2.69
Column	2.74E+06	3.	912365.4	14.54	0.	2.69
Interaction	3.66E+05	9.	40654.79	0.65	0.75	1.96
Within	7.03E+06	112.	62764.39			
Total	1.06E+07	127.				

This shows the ANOVA summary for t, the time taken by the subject to answer the question using the hypertext.

On the left are the values obtained by the subjects in the four treatments (Tr.1 ... Tr.4) for the four questions (Qu. 1 ...Qu. 4), and on the right, a summary of the ANOVA showing the means and variances for the four treatments over the four questions (trials). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the treatments (Sample), for the questions (Column), and for the interaction between these (Interaction).

Only the differences between the 'Column' means were significant, as only ($F_{Column} > Fcrit_{Column}$).

7.7. ANOVA summary for Expt. 2.1: Sn

	Qu. 1	Qu. 2	Qu. 3	Qu. 4
Tr.1	3.	4.	3.	3.
	36.	24.	3.	15.
	0.	0.	0.	0.
	6.	9.	8.	8.
	16.	0.	0.	0.
	4.	0.	30.	19.
	35.	2.	19.	5.
	17.	0.	55.	20.
Tr.2	0.	5.	14.	0.
	6.	4.	11.	12.
	12.	0.	4.	10.
	0.	0.	0.	0.
	6.	27.	7.	0.
	0.	0.	0.	0.
	0.	0.	0.	3.
	0.	0.	0.	0.
Tr.3	0.	0.	0.	0.
	44.	10.	33.	19.
	0.	4.	0.	10.
	0.	0.	0.	0.
	0.	0.	0.	0.
	0.	0.	0.	12.
	2.	0.	0.	9.
	0.	0.	0.	0.
Tr.4	13.	3.	0.	0.
	4.	3.	12.	4.
	3.	2.	8.	39.
	3.	0.	0.	2.
	0.	0.	0.	17.
	0.	0.	4.	0.
	0.	6.	0.	13.
	10.	10.	7.	0.

Anova: Two-Factor With Replication

Summary

	Qu. 1	*Qu. 2*	*Qu. 3*	*Qu. 4*	*Total*
		Tr.1			
Count	8.	8.	8.	8.	32.
Sum	117.	39.	118.	70.	344.
Average	14.625	4.875	14.75	8.75	43.
Variance	202.268	69.554	375.357	67.357	714.536
		Tr.2			
Count	8.	8.	8.	8.	32.
Sum	24.	36.	36.	25.	121.
Average	3.	4.5	4.5	3.125	15.125
Variance	20.571	86.857	31.429	24.982	163.839
		Tr.3			
Count	8.	8.	8.	8.	32.
Sum	46.	14.	33.	50.	143.
Average	5.75	1.75	4.125	6.25	17.875
Variance	239.357	13.071	136.125	53.357	441.911
		Tr.4			
Count	8.	8.	8.	8.	32.
Sum	33.	24.	31.	75.	163.
Average	4.125	3.	3.875	9.375	20.375
Variance	23.839	12.286	21.839	185.125	243.089
	Total				
Count	32.	32.	32.	32.	
Sum	220.	113.	218.	220.	
Average	27.5	14.125	27.25	27.5	
Variance	486.036	181.768	564.75	330.821	

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	980.773	3.	326.924	3.346	0.022	2.686
Column	265.086	3.	88.362	0.904	0.441	2.686
Interaction	607.445	9.	67.494	0.691	0.716	1.964
Within	10943.625	112.	97.711			
Total	12796.93	127.				

This shows the ANOVA summary for Sn, the number of link traversals made which formed part of a series of 'Prev' or 'Next' links.

On the left are the values obtained by the subjects in the four treatments (Tr.1 ... Tr.4) for the four questions (Qu. 1 ...Qu. 4), and on the right, a summary of the ANOVA showing the means and variances for the four treatments over the four questions (trials). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the treatments (Sample), for the questions (Column), and for the interaction between these (Interaction).

Only the differences between the 'Sample' means were significant, as only ($F_{Sample} > Fcrit_{Sample}$).

7.8. ANOVA summary for Expt. 2.2, Trial 1: P_E

A	B	C	D
0	1	0	1
0	1	0	0
0	1	0	0
1	0	0	0
0	1	0	0
0	0	1	1
0	1	0	0
1	0	1	1
0	1	0	0
1	1	0	0
0	0	0	0
0	1	0	0
0	0	0	1
1	0	0	1
0	1	1	0
0	1	0	0
0	1	0	0
0	0	0	0
1	1	0	0
1	0	0	1
0	1	0	0
0	1	0	0
0	1	0	0
0	1	0	0
1	0	1	1
0	1	0	0

Anova: Two-Factor Without Replication

Summary	*Count*	*Sum*	*Average*	*Variance*
Row 1	4	2	0.5	0.333333
Row 2	4	1	0.25	0.25
Row 3	4	1	0.25	0.25
Row 4	4	1	0.25	0.25
Row 5	4	1	0.25	0.25
Row 6	4	2	0.5	0.333333
Row 7	4	1	0.25	0.25
Row 8	4	3	0.75	0.25
Row 9	4	1	0.25	0.25
Row 10	4	2	0.5	0.333333
Row 11	4	0	0	0
Row 12	4	1	0.25	0.25
Row 13	4	1	0.25	0.25
Row 14	4	2	0.5	0.333333
Row 15	4	2	0.5	0.333333
Row 16	4	1	0.25	0.25
Row 17	4	1	0.25	0.25
Row 18	4	0	0	0
Row 19	4	2	0.5	0.333333
Row 20	4	2	0.5	0.333333
Row 21	4	1	0.25	0.25
Row 22	4	1	0.25	0.25
Row 23	4	1	0.25	0.25
Row 24	4	1	0.25	0.25
Row 25	4	3	0.75	0.25
Row 26	4	1	0.25	0.25
Para. A	26	7	0.269231	0.204615
Para. B	26	17	0.653846	0.235385
Para. C	26	4	0.153846	0.135385
Para. D	26	7	0.269231	0.204615

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	3.471154	25	0.138846	0.64967	0.886795	1.653206
Columns	3.721154	3	1.240385	5.803839	0.00127	2.726594
Error	16.02885	75	0.213718			
Total	23.22115	103				

This shows the ANOVA summary for the responses of subjects asked whether the target paragraphs (A, B, C or D) were what they expected to follow the prompt paragraph.

On the left are shown, for each of the 26 subjects a '1' if they responded "Yes" (or a '0' for "No") to the question "Is this paragraph what you expected to follow the combination of the previous paragraph and link?". Values are arranged in columns for these responses for each of the paragraphs in this trial, A, B, C and D. On the right, a summary of the ANOVA showing the means and variances over the subjects (Row 1-26) and over the target paragraphs (Para A-D). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the subjects (Rows), and for the questions (Column).

The differences between the 'Column' means were significant, as ($F_{Column} > Fcrit_{Column}$).

7.9. ANOVA summary for Expt. 2.2, Trial 1: Ps

A	B	C	D
1	1	0	1
1	0	0	0
1	1	0	0
0	0	0	0
1	1	1	0
1	1	0	0
0	1	1	1
1	0	0	0
0	1	0	0
1	1	0	0
1	1	0	1
1	1	0	0
1	1	0	0
1	0	0	0
0	1	0	0
0	1	0	1

Anova: Two-Factor Without Replication

Summary	*Count*	*Sum*	*Average*	*Variance*
Row 1	4	3	0.75	0.25
Row 2	4	1	0.25	0.25
Row 3	4	2	0.5	0.333333
Row 4	4	0	0	0
Row 5	4	3	0.75	0.25
Row 6	4	2	0.5	0.333333
Row 7	4	3	0.75	0.25
Row 8	4	1	0.25	0.25
Row 9	4	1	0.25	0.25
Row 10	4	2	0.5	0.333333
Row 11	4	3	0.75	0.25
Row 12	4	2	0.5	0.333333
Row 13	4	2	0.5	0.333333
Row 14	4.	1.	0.25	0.25
Row 15	4.	1.	0.25	0.25
Row 16	4.	2.	0.5	0.333
Para. A	16.	11.	0.688	0.229
Para. B	16.	12.	0.75	0.2
Para. C	16.	2.	0.125	0.117
Para. D	16.	4.	0.25	0.2

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	3.109	15.	0.207	1.155	0.34	1.895
Columns	4.672	3.	1.557	8.675	0.	2.812
Error	8.078	45.	0.18			
Total	15.859	63.				

This shows the ANOVA summary for the responses of subjects asked whether the target paragraphs (A, B, C or D) were strongly linked to the prompt paragraph.

On the left are shown, for each of the 16 subjects a '1' if they responded "Yes" (or a '0' for "No") to the question "Is this paragraph strongly linked to the previous one?". Values are arranged in columns for these responses for each of the paragraphs in this trial, A, B, C and D. On the right, a summary of the ANOVA showing the means and variances over the subjects (Row 1-16) and over the target paragraphs (Para A-D). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the subjects (Rows), and for the questions (Column).

The differences between the 'Column' means were significant, as ($F_{Column} > Fcrit_{Column}$).

7.10. ANOVA summary for Expt. 2.2, Trial 2: P_E

A	B	C	D
1	1	0	0
0	1	1	0
0	1	0	1
0	1	1	0
1	0	0	0
1	1	0	0
0	1	0	0
0	1	0	0
1	1	1	0
0	1	1	1
0	0	0	0
1	1	0	0
1	0	0	0
0	1	1	0
1	1	1	1
1	1	0	1
1	0	0	0
0	1	0	0
0	0	0	1
0	1	0	1
0	0	0	0
0	1	0	0
1	0	0	0
0	1	0	0
0	1	1	0
0	0	0	0

Anova: Two-Factor Without Replication

Summary	*Count*	*Sum*	*Average*	*Variance*
Row 1	4	2	0.5	0.333333
Row 2	4	2	0.5	0.333333
Row 3	4	2	0.5	0.333333
Row 4	4	2	0.5	0.333333
Row 5	4	1	0.25	0.25
Row 6	4	2	0.5	0.333333
Row 7	4	1	0.25	0.25
Row 8	4	1	0.25	0.25
Row 9	4	3	0.75	0.25
Row 10	4	3	0.75	0.25
Row 11	4	0	0	0
Row 12	4	2	0.5	0.333333
Row 13	4	1	0.25	0.25
Row 14	4	2	0.5	0.333333
Row 15	4	4	1	0
Row 16	4	3	0.75	0.25
Row 17	4	1	0.25	0.25
Row 18	4	1	0.25	0.25
Row 19	4	1	0.25	0.25
Row 20	4	2	0.5	0.333333
Row 21	4	0	0	0
Row 22	4	1	0.25	0.25
Row 23	4	1	0.25	0.25
Row 24	4	1	0.25	0.25
Row 25	4	2	0.5	0.333333
Row 26	4	0	0	0
Para. A	26	10	0.384615	0.246154
Para. B	26	18	0.692308	0.221538
Para. C	26	7	0.269231	0.204615
Para. D	26	6	0.230769	0.184615

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	6.086538	25	0.243462	1.190596	0.276497	1.653206
Columns	3.413462	3	1.137821	5.564263	0.001677	2.726594
Error	15.33654	75	0.204487			
Total	24.83654	103				

This shows the ANOVA summary for the responses of subjects asked whether the target paragraphs (A, B, C or D) were what they expected to follow the prompt paragraph.

On the left are shown, for each of the 26 subjects a '1' if they responded "Yes" (or a '0' for "No") to the question "Is this paragraph what you expected to follow the combination of the previous paragraph and link?". Values are arranged in columns for these responses for each of the paragraphs in this trial, A, B, C and D. On the right, a summary of the ANOVA showing the means and variances over the subjects (Row 1-26) and over the target paragraphs (Para A-D). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the subjects (Rows), and for the questions (Column).

The differences between the 'Column' means were significant, as ($F_{Column} > Fcrit_{Column}$).

7.11. ANOVA summary for Expt. 2.2, Trial 2: Ps

A	B	C	D
0	1	1	1
1	1	0	1
1	1	1	1
1	1	0	1
1	1	0	1
1	1	1	0
0	1	1	1
0	1	0	1
1	1	1	1
0	1	0	0
1	0	0	1
0	1	0	0
0	0	0	1
1	0	0	0
1	1	1	1
1	0	1	1

Anova: Two-Factor Without Replication

Summary	*Count*	*Sum*	*Average*	*Variance*
Row 1	4	3	0.75	0.25
Row 2	4	3	0.75	0.25
Row 3	4	4	1	0
Row 4	4	3	0.75	0.25
Row 5	4	3	0.75	0.25
Row 6	4	3	0.75	0.25
Row 7	4	3	0.75	0.25
Row 8	4	2	0.5	0.3333
Row 9	4	4	1	0
Row 10	4	1	0.25	0.25
Row 11	4	2	0.5	0.3333
Row 12	4	1	0.25	0.25
Row 13	4	1	0.25	0.25
Row 14	4.	1.	0.25	0.25
Row 15	4.	4.	1.	0.
Row 16	4.	3.	0.75	0.25
Para. A	16.	10.	0.625	0.25
Para. B	16.	12.	0.75	0.2
Para. C	16.	7.	0.438	0.263
Para. D	16.	12.	0.75	0.2

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	4.484	15.	0.299	1.462	0.161	1.895
Columns	1.047	3.	0.349	1.706	0.179	2.812
Error	9.203	45.	0.205			
Total	14.734	63.				

This shows the ANOVA summary for the responses of subjects asked whether the target paragraphs (A, B, C or D) were strongly linked to the prompt paragraph.

On the left are shown, for each of the 16 subjects a '1' if they responded "Yes" (or a '0' for "No") to the question "Is this paragraph strongly linked to the previous one?". Values are arranged in columns for these responses for each of the paragraphs in this trial, A, B, C and D. On the right, a summary of the ANOVA showing the means and variances over the subjects (Row 1-16) and over the target paragraphs (Para A-D). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the subjects (Rows), and for the questions (Column).

The differences between the 'Column' means were not significant, as ($F_{Column} < Fcrit_{Column}$).

7.12. ANOVA summary for Expt. 2.2, Trial 3: P_E

A	B	C	D
0	1	0	1
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	1
0	1	0	0
1	0	0	0
1	0	0	0
0	0	0	0
0	1	1	0
1	0	0	0
1	1	1	0
1	0	0	0
0	1	0	0
0	1	1	1
1	0	0	0
1	1	1	0
0	1	0	0
0	0	1	0
0	1	0	1
1	0	0	0
0	0	0	0
1	0	0	0
0	0	0	0
0	0	1	0
0	1	1	0

Anova: Two-Factor Without Replication

Summary	*Count*	*Sum*	*Average*	*Variance*
Row 1	4	2	0.5	0.333333
Row 2	4	0	0	0
Row 3	4	0	0	0
Row 4	4	0	0	0
Row 5	4	1	0.25	0.25
Row 6	4	1	0.25	0.25
Row 7	4	1	0.25	0.25
Row 8	4	1	0.25	0.25
Row 9	4	0	0	0
Row 10	4	2	0.5	0.333333
Row 11	4	1	0.25	0.25
Row 12	4	3	0.75	0.25
Row 13	4	1	0.25	0.25
Row 14	4	1	0.25	0.25
Row 15	4	3	0.75	0.25
Row 16	4	1	0.25	0.25
Row 17	4	3	0.75	0.25
Row 18	4	1	0.25	0.25
Row 19	4	1	0.25	0.25
Row 20	4	2	0.5	0.333333
Row 21	4	1	0.25	0.25
Row 22	4	0	0	0
Row 23	4	1	0.25	0.25
Row 24	4	0	0	0
Row 25	4	1	0.25	0.25
Row 26	4	2	0.5	0.333333
Para. A	26	9	0.346154	0.235385
Para. B	26	10	0.384615	0.246154
Para. C	26	7	0.269231	0.204615
Para. D	26	4	0.153846	0.135385

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	5.346154	25	0.213846	1.055696	0.412792	1.653206
Columns	0.807692	3	0.269231	1.329114	0.27128	2.726594
Error	15.19231	75	0.202564			
Total	21.34615	103				

This shows the ANOVA summary for the responses of subjects asked whether the target paragraphs (A, B, C or D) were what they expected to follow the prompt paragraph.

On the left are shown, for each of the 26 subjects a '1' if they responded "Yes" (or a '0' for "No") to the question "Is this paragraph what you expected to follow the combination of the previous paragraph and link?". Values are arranged in columns for these responses for each of the paragraphs in this trial, A, B, C and D. On the right, a summary of the ANOVA showing the means and variances over the subjects (Row 1-26) and over the target paragraphs (Para A-D). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the subjects (Rows), and for the questions (Column).

The differences between the 'Column' means were not significant, as ($F_{Column} < Fcrit_{Column}$).

7.13. ANOVA summary for Expt. 2.2, Trial 3: P_S

A	B	C	D
0	1	0	1
0	1	0	1
0	1	0	1
0	1	0	0
0	1	0	1
0	0	0	0
0	1	0	0
0	0	0	1
0	0	0	1
0	0	0	0
0	1	1	0
0	1	0	0
0	0	0	0
0	0	0	0
0	1	0	1
0	0	0	0

Anova: Two-Factor Without Replication

Summary	*Count*	*Sum*	*Average*	*Variance*
Row 1	4	2	0.5	0.333
Row 2	4	2	0.5	0.333
Row 3	4	2	0.5	0.333
Row 4	4	1	0.25	0.25
Row 5	4	2	0.5	0.333
Row 6	4	0	0.	0.
Row 7	4	1	0.25	0.25
Row 8	4	1	0.25	0.25
Row 9	4	1	0.25	0.25
Row 10	4	0	0.	0.
Row 11	4	2	0.5	0.333
Row 12	4	1	0.25	0.25
Row 13	4	0	0.	0.
Row 14	4.	0.	0.	0.
Row 15	4.	2.	0.5	0.333
Row 16	4.	0.	0.	0.
Para. A	16.	0.	0.	0.
Para. B	16.	9.	0.563	0.263
Para. C	16.	1.	0.063	0.063
Para. D	16.	7.	0.438	0.263

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	2.734	15.	0.182	1.35	0.214	1.895
Columns	3.672	3.	1.224	9.062	0.	2.812
Error	6.078	45.	0.135			
Total	12.484	63.				

This shows the ANOVA summary for the responses of subjects asked whether the target paragraphs (A, B, C or D) were strongly linked to the prompt paragraph.

On the left are shown, for each of the 16 subjects a '1' if they responded "Yes" (or a '0' for "No") to the question "Is this paragraph strongly linked to the previous one?". Values are arranged in columns for these responses for each of the paragraphs in this trial, A, B, C and D. On the right, a summary of the ANOVA showing the means and variances over the subjects (Row 1-16) and over the target paragraphs (Para A-D). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the subjects (Rows), and for the questions (Column).

The differences between the 'Column' means were significant, as ($F_{Column} > Fcrit_{Column}$).

7.14. ANOVA summary for Expt. 2.2, Trial 4: P_E

A	B	C	D
1	1	1	1
1	1	0	0
1	1	0	0
0	0	0	1
1	1	1	0
1	1	1	0
0	1	0	0
1	1	0	0
1	1	1	0
1	1	1	0
1	1	0	0
1	1	0	0
1	0	0	0
0	0	1	1
1	1	1	1
1	1	0	0
1	1	0	0
0	1	0	0
1	0	0	0
0	0	1	0
1	1	0	0
1	1	0	0
1	1	0	0
1	1	0	0
1	0	1	0
0	1	0	0

Anova: Two-Factor Without Replication

Summary	*Count*	*Sum*	*Average*	*Variance*
Row 1	4	4	1	0
Row 2	4	2	0.5	0.333333
Row 3	4	2	0.5	0.333333
Row 4	4	1	0.25	0.25
Row 5	4	3	0.75	0.25
Row 6	4	3	0.75	0.25
Row 7	4	1	0.25	0.25
Row 8	4	2	0.5	0.333333
Row 9	4	3	0.75	0.25
Row 10	4	3	0.75	0.25
Row 11	4	2	0.5	0.333333
Row 12	4	2	0.5	0.333333
Row 13	4	1	0.25	0.25
Row 14	4	2	0.5	0.333333
Row 15	4	4	1	0
Row 16	4	2	0.5	0.333333
Row 17	4	2	0.5	0.333333
Row 18	4	1	0.25	0.25
Row 19	4	1	0.25	0.25
Row 20	4	1	0.25	0.25
Row 21	4	2	0.5	0.333333
Row 22	4	2	0.5	0.333333
Row 23	4	2	0.5	0.333333
Row 24	4	2	0.5	0.333333
Row 25	4	2	0.5	0.333333
Row 26	4	1	0.25	0.25
Para. A	26	20	0.769231	0.184615
Para. B	26	20	0.769231	0.184615
Para. C	26	9	0.346154	0.235385
Para. D	26	4	0.153846	0.135385

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	4.740385	25	0.189615	1.033543	0.438276	1.653206
Columns	7.490385	3	2.496795	13.60936	3.54E-07	2.726594
Error	13.75962	75	0.183462			
Total	25.99038	103				

This shows the ANOVA summary for the responses of subjects asked whether the target paragraphs (A, B, C or D) were what they expected to follow the prompt paragraph.

On the left are shown, for each of the 26 subjects a '1' if they responded "Yes" (or a '0' for "No") to the question "Is this paragraph what you expected to follow the combination of the previous paragraph and link?". Values are arranged in columns for these responses for each of the paragraphs in this trial, A, B, C and D. On the right, a summary of the ANOVA showing the means and variances over the subjects (Row 1-26) and over the target paragraphs (Para A-D). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the subjects (Rows), and for the questions (Column).

The differences between the 'Column' means were significant, as ($F_{Column} > Fcrit_{Column}$).

7.15. ANOVA summary for Expt. 2.2, Trial 4: P_S

A	B	C	D
0	1	1	0
1	1	1	0
1	1	1	1
1	1	1	0
0	1	1	0
1	1	1	0
1	1	1	0
0	1	1	0
1	1	1	1
1	0	1	0
1	1	1	0
1	1	1	0
1	1	1	0
0	0	0	0
1	1	1	0
1	1	1	0

Anova: Two-Factor Without Replication

Summary	*Count*	*Sum*	*Average*	*Variance*
Row 1	4.	2.	0.5	0.333
Row 2	4.	3.	0.75	0.25
Row 3	4.	4.	1.	0.
Row 4	4.	3.	0.75	0.25
Row 5	4.	2.	0.5	0.333
Row 6	4.	3.	0.75	0.25
Row 7	4.	3.	0.75	0.25
Row 8	4.	2.	0.5	0.333
Row 9	4.	4.	1.	0.
Row 10	4.	2.	0.5	0.333
Row 11	4.	3.	0.75	0.25
Row 12	4.	3.	0.75	0.25
Row 13	4.	3.	0.75	0.25
Row 14	4.	0.	0.	0.
Row 15	4.	3.	0.75	0.25
Row 16	4.	3.	0.75	0.25
Para. A	16.	12.	0.75	0.2
Para. B	16.	14.	0.875	0.117
Para. C	16.	15.	0.938	0.063
Para. D	16.	2.	0.125	0.117

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	3.359	15.	0.224	2.471	0.01	1.895
Columns	6.672	3.	2.224	24.54	0.	2.812
Error	4.078	45.	0.091			
Total	14.109	63.				

This shows the ANOVA summary for the responses of subjects asked whether the target paragraphs (A, B, C or D) were strongly linked to the prompt paragraph.

On the left are shown, for each of the 16 subjects a '1' if they responded "Yes" (or a '0' for "No") to the question "Is this paragraph strongly linked to the previous one?". Values are arranged in columns for these responses for each of the paragraphs in this trial, A, B, C and D. On the right, a summary of the ANOVA showing the means and variances over the subjects (Row 1-16) and over the target paragraphs (Para A-D). At the bottom are the sum of squares (SS), degrees of freedom (df), Mean Squares (MS), F value, and critical F value for the subjects (Rows), and for the questions (Column).

The differences between the 'Column' means were significant, as ($F_{Column} > Fcrit_{Column}$).