Designing and Evaluating Information Spaces: A Navigational Perspective

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A thesis submitted in partial fulfilment of the requirements of Napier University for the degree of Doctor of Philosophy

May 2003

Abstract

Navigation in two and three dimensional electronic environments has become an important usability issue. Research into the use of hypertext systems would appear to suggest that people suffer from a variety of navigational problems in these environments. In addition users also encounter problems in 3D environments and in applications software. Therefore in order to enhance the ease of use from the point of view of preventing errors and making it more pleasurable the navigating in information space approach to HCI has been adopted.

The research presented in this thesis examines whether the study of real world environments, in particular aspects of the built environment, urban planning and environmental psychology are beneficial in the development of guidelines for interface design and evaluation. In doing so the thesis examines three main research questions (1) is there a transfer of design knowledge from real to electronic spaces? (2) can concepts be provided in a series of useful guidelines? (3) are the guidelines useful for the design and evaluation of electronic spaces?

Based upon the results of the two main studies contained within this thesis it is argued that the navigational perspective is one which is relevant to user interface design and evaluation and that navigation in electronic spaces is comparable to but not identical with actions within the real world. Moreover, the studies pointed to the validity of the core concepts when evaluating 2D and 3D spaces and designing 3D spaces. The thesis also points to the relevancy of the overall design guidance in 2D and 3D environments and the ability to make such information available through a software tool.

Acknowledgements

Like many things it is impossible to claim that without the support, inspiration and co-operation of others this thesis would ever have been completed. In terms of helping along the way with this thesis I must of course thank Prof. David Benyon and Dr. Alan J. Munro who have been excellent (if at times picky) supervisors and Prof. Jessie Kennedy my panel chair for sticking to the rules when it was needed. Without their commitment, dedication, help and inspiration I doubt many of the aspects of this thesis would have come to light. This leads me to the next group those who I have worked and studied with along the way. These include the co-conspirators in the PERSONA project who inspired, critiqued and help along the way including Dr. Kristina Höök, Dr. Martin Svensson, Dr. Per Persson, Marie Sjölinder, and Dr. Nils Dählbeck. Acknowledgements are also due to those who have helped in some of the studies including Anders Hedman, Soren Lenman, Paul Johannesson, members of the CO-NEXUS project and the 1999-2000 BSc HCI students at Napier University.

Other people who have helped include my mother (Carlyn McCall), Nicola Beasley and Dr. Leena Patel who have proofread this thesis and Sebastian Johansson for helping with Swedish translations.

Acknowledgements for general support, help and inspiration are due to the entire HCI group at Napier University in particular Dr Phil Turner and Dr Susan Turner who I worked with on the DISCOVER project. Other specific acknowledgements are also due to Lynne Baillie, Jon Sykes and Dr Catrionia Macaulay. Additional acknowledgements in this area are also due to those in the HUMLE group at SICS in Sweden and the participants of various conferences, workshops and seminars along the way.

Another group of people who I need to thank are friends and family for their support. Firstly my family who have provided support, financial assistance and general tolerance along the way. In addition my friends from Sweden who I met (and won't forget) while studying at SICS and finally my current and past flatmates in Edinburgh who have put up with a lot of moaning.

I'd also like to thank those who inspired the HCI in me, namely Prof. Alan F. Newell of Dundee University. Had I not studied his somewhat quirky HCI module back in the mid-nineties then this thesis would have happened. Acknowledgements at this point are also due to Dr. Peter Gregor, Chris Hand and

Acknowledgements

Howell Istance (your eye tracker will never be forgotten). Had these people not inspired me in some way, I'd never have embarked upon a PhD in the first place.

Finally this thesis is dedicated to those who have sadly passed away before their time while I've been studying: Ben Walton, Dr. Sandra Foubister, Reginald Levine and Paul Tracey.

Rod McCall
Leith, Edinburgh
September 2002

Publications arising from this thesis

2002

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Chapter 1

Introduction

This chapter provides an overview of the background to this thesis, its research objectives, and the chapters and studies contained within.

1.1 Introduction

This thesis examines the design and evaluation of 2D and 3D electronic spaces from the *navigation in information space* perspective (Benyon and Höök, 1997; Benyon, 1998). The thesis takes the view that disorientation is an increasingly common feeling for many computer users and can occur within a range of spaces, including: 3D virtual environments (Darken, 1995; Waller, 1999); web pages (Kim and Hirtle, 1995; McDonald and Stevenson, 1996; Byrne, John, Wehrle & Crow, 1999); and in a range of software systems, such as ambulance despatch (Wong, O'Hare & Sallis, 1998). As a result, designers and evaluators of electronic environments need to gain a better understanding of how the structure of an environment can aid users in their navigational activities. This need has led to a greater discussion of the *navigation in information space* perspective as a means of designing and evaluating user interfaces. This perspective draws upon ideas from a range of backgrounds including cognitive psychology, architecture, theatre and cinema as a means of gaining a better understanding of the navigational behaviour of users.

This chapter will provide an overview to the main themes within this thesis. Section 1.2 summarises some of the key themes while section 1.3 discusses the main research objectives and section 1.4 examines the thesis structure and the experimental methods employed. The remaining sections 1.5 and 1.6 summarise the findings and limitations of the research, and 1.7 provides a summary.

1.2 Overview of Key Themes

1.2.1 Navigation and Information Spaces

This thesis takes a navigational perspective by developing a series of guidelines known as ENISpace (Evaluating Navigation in Information Spaces) which can be used by designers and evaluators to reduce navigational problems in electronic environments. In doing so it builds upon the underlying concept of navigation which broadly speaking is a complex task consisting of a range of activities, types of environmental knowledge and interactions (see Chapters 2 and 3 for more information). As a result, it is important to understand how these aspects will impact upon the navigational behaviour of people and how cues can be used to support their activities and knowledge a person posses of their environment.

The thesis builds on the navigational perspective of usability proposed by Benyon and Höök (1997) which places emphasis on how people interact within a space, rather than viewing them as outside it trying to manipulate objects. Consequently, it contrasts with the traditional views of usability such as the gulfs of execution and evaluation (Norman and Draper, 1986), measuring task completion times (Card, Moran & Newell, 1980), or ease of learning (Dowell and Long, 1998). A navigational perspective on usability examines how the artefacts within a space will affect the experience of end users and how users create or produce their own place (Lefebvre, 1991), rather than simply moving around a space created by others. It also examines how people move within, between and through spaces (Benyon and Höök, 1997) and how they view, create, interpret and use information artefacts (Green and Benyon, 1996; Harper, 1998; Munro, 1998). Artefacts within 3D virtual environments include the basic navigation controls, through to the use of texture mappings on the walls of rooms and corridors. Within 2D interfaces artefacts include aspects such as a cell in a spreadsheet, the entire spreadsheet or one of the pull down menus.

1.2.2 Navigation in Existing Usability Methods

ENISpace was developed in order to place emphasis upon navigational issues during the design and evaluation of electronic environments. This is because traditional 2D usability methods such as Heuristic Evaluation (Nielsen, 1999), GOMS (John, 1996) and Cognitive Walkthrough (Lewis, 1997) do not cover navigational issues in any detail. The situation varies slightly when examining usability methods for 3D environments where research into navigation has been more thorough. Although the common sets of guidelines or research (Charitos, 1997; COVEN, 1997; Ingram, Benford and Bowers 1996; Kalawsky, 1999; Kaur, 1998) do examine navigation; they often do not provide sufficient guidance, are at too high a level to be useful or simply replicate the work of Lynch (1960) in relation common patterns (or layouts) which exist within the built environment. A thorough examination of usability and navigation can be found in Chapter 3.

1.3 Research objectives

The objective of this thesis is to examine the applicability of the navigational perspective (through concepts and guidelines) to the design and evaluation of 2D and 3D electronic information spaces. At the time of writing, several authors have already examined certain aspects of navigation. However, in contrast with previous works (Ark and Dryer, 1998; Charitos, 1997; COVEN, 1997; Heffron, Dillon & Mostafa, 1996; Kaur, 1998; Waller, 1999), this thesis looks at navigation in the context of both two and three-dimensional environments. It also sets out to provide a greater degree of detail within the guidelines. The thesis examines three research questions:

(1) Is there a transfer of design knowledge from real to electronic spaces?

(2) Can concepts be provided in a series of useful guidelines?

(3) Are the guidelines useful for the design and evaluation of electronic spaces?

These three research questions provide the general framework in which the literature review, development of the guidelines, and subsequent studies were carried out. The studies often make use of several navigation cues at one time and in doing so the studies recognise that it is often the relationships between cues rather then any one individual cue, that will shape navigational behaviour. This study method is similar to that of Lynch (1960), Abu-Ghazzeh (1996) and Bittner (1992) where the participants used real world environments consisting of many cues.

1.4 Thesis Structure and Methods employed

This thesis consists of seven chapters. It initially explores the issue of navigation from the perspective of the built environment (Chapter 2), in particular aspects such as environmental knowledge, models of navigation and the types of cues that can be used to help users. The aim is to provide a range of theories and examples from environmental psychology, spatial cognition, architecture, town planning and the design of signs.

Chapter 3 examines navigation from the perspective of electronic spaces; in particular how navigation remains a problem for many users. The chapter discusses interface design and evaluation methodologies, different types of environments and tools that have helped improve the navigability of electronic spaces.

An initial pilot study (Chapter 4) explores some early navigational guidelines (Benyon and McCall, 1998) with the aim of seeing whether they were useful for evaluating an internet application. This study used a range of evaluation methods such as direct observation, traditional usability methods, navigational guidelines, and independent evaluators. The pilot study examined whether there was a transfer of knowledge between real and virtual environments and examined whether the basic concepts were useful for evaluation. This study clearly points to the transfer of knowledge between real and virtual spaces and the usefulness of navigational concepts for evaluation. The chapter also contains an overview of a revised version of the guidelines known as ENISpace (Evaluating Navigation in Information Spaces). This new version brought in more aspects of the literature review in Chapters 2 and 3, addressed some of the problems with the early guidelines and was also implemented in software.

The study in Chapter 5 uses ENISpace in the evaluation of a complex information space consisting of 2D and 3D elements. The study used 17 independent evaluators who were asked to write a report on the usability of the system using ENISpace as the method of evaluation. The report contained their comments in relation to each ENISpace guideline and a summary of the problems found. The results clearly indicate that ENISpace identified a series of relevant issues. Moreover, the study demonstrated that (despite limitations) navigational concepts can provide a series of useful guidelines and there is a mapping of ideas between real and virtual environments.

The final study in Chapter 6 used ENISpace to design two 3D virtual environments. The study used a range of methods including direct observation, subjective satisfaction questionnaires and sketch maps to uncover the relative benefits of various design concepts. This study clearly indicated the benefit of most aspects of ENISpace and in doing so provided clear evidence of the transfer of knowledge between real and 3D virtual environments.

Chapter 7 provides a summary of the main theories, objectives and results of the thesis. The chapter concludes that the *navigation in information space* perspective is relevant with the design and evaluation of 2D and 3D electronic spaces.

1.5 Research Issues

This thesis makes a range of contributions to the field, in particular it examines the overall effectiveness of the *navigation in information space* perspective as a means of designing and evaluating user interfaces. There are a range of background issues that impact on the results:

- *The studies examine a combination of cues and therefore it is not a study of how to apply individual components.* One of the strengths of this thesis is that it considers navigation as an activity made up of a range of cue use strategies, all of which to a greater or lesser degree depend upon the use of other cues within the environment.

- *A substantial part of the studies were conducted using qualitative rather than purely quantitative data* and as a result there is a degree of subjectivity in the interpretation. However, the quantity of data analysed and the use of corroboration between different types of data should help overcome some of the problems inherent from such studies.

- *There are areas that are ignored within the guidelines.* The guidelines do not attempt to cover all aspects of navigation, in particular social navigation.

- *This thesis does not seek to validate any underlying models of navigation or environmental knowledge.* While the thesis makes use of ideas from navigational models and behaviour, it does not seek to validate any aspects of these items. Rather, it takes the view that there are observable similarities in behaviour but that the underlying cognitive models may vary.

1.6 Contributions

This thesis has a range of contributions for the field of HCI and also to specific interest groups.

1. The studies in chapters 4 to 6 provide a validation of the *navigation in information space* perspective as being relevant to user interface design and evaluation.

2. The empirical work in chapter 6 illustrates that the navigational behaviour of people in real and electronic environments is very similar. However, although the behaviours are similar it is not possible to say whether people are using the same cognitive processes.

3. The thesis provides a set of detailed high-level design guidance which is applicable across a range of domains.

4. The empirical work in chapter 5 indicates the validity of the overall concepts contained in the guidelines in relation to the evaluation of 2D and 3D environments.

5. The empirical work in chapter 6 illustrates the validity of the overall concepts in relation to the design of 3D virtual environments.

6. The thesis discusses the development of a software tool which contains the ENISpace guidelines and supporting features. However, it is acknowledged that it requires further development.

1.7 Summary

Throughout the thesis the aim is to explore navigation from a wider perspective by drawing on aspects from environmental psychology, urban planning, town planning and architecture, while at the same time considering issues from HCI. The thesis explores the design and development of navigational guidelines, and the use of them by a range of people (designers, evaluators and end users) in different contexts (2D and 3D environments). In doing so the thesis provides six major contributions and an early methodology.

Chapter 2

The Built Environment

"MAN SHAPES BUILDING AND BUILDINGS SHAPE US".

Winston Churchill, 1943

The following chapter presents a review of the literature in relation to real world environments. The chapter highlights the emergence of a number of underlying themes such as existentialism, meaning, social interaction and individual preferences and how these impact upon the conceptualisation of spaces held by individuals. The chapter examines these aspects from the perspective of physical properties of the environment such as paths, places and signs.

2.1 Introduction

Navigation within the built environment is a complex task encompassing a range of activities and behaviours. Moreover, the ability of people to navigate is affected by environmental features, social interactions and emotions. This chapter draws on the navigational behaviour of people within a range of environments, for example, in towns and cities, the natural environment (e.g. orienteering) and within buildings (e.g. libraries). The main emphasis is on examining navigation from wider perspectives such as environmental and cognitive psychology, architecture and how models of interaction, views of objects and the artefacts will shape a person's navigational behaviour. This chapter also looks at how a person's current and prior experiences will shape his or her navigational behaviour; in particular, how the experiential approach (discussed in this chapter) can be used to inform the design of environments.

This chapter (and ultimately the thesis) takes an experientialist viewpoint based on observed behaviours and underlying cognitive models of navigation, although it does not seek to validate the latter. The experiential viewpoint primarily views navigation as a product of what paths people choose to take. The paths people choose will affect where they go, the experiences they will have and the meanings they attach to an area or groups of areas. This process of attaching meanings will also affect their behaviours within the given spaces and ultimately the models (or internal maps) they create of the environment. In addition, the chapter also takes the view that this experientialist viewpoint results in a situation where no single environmental property (e.g. a path) can be considered in isolation and, therefore, it is the relationship between the various properties that will ultimately affect people's navigational behaviour within the space.

This chapter starts with a discussion on how people perceive, conceive and interact within spaces. It then discusses environmental knowledge and behaviour. Having discussed these wider aspects it then provides a review of design features in the physical environment.

2.2 Perceiving, Conceiving and Interaction within Spaces

A number of authors have commented on how people perceive, conceive and interact within a space (Benyon and Höök, 1997; Broadbent, Bunt & Llorens, 1980a; Broadbent, Bunt & Jencks, 1980b; Buttimer, 1980; Harrison and Howards, 1980; Lynch, 1960; Ladd, 1970; Norberg-Schultz, 1971; Perziosi, 1979). These factors include the ability to identify objects, structure the environment into a stable schema and finally abstract a meaning from it (see Table 2-1). The ability to *identify*, *structure* and *attach meaning* to aspects of the environment plays an important role in navigation and the construction of environmental knowledge. Initially, the ability to identify elements within a space is critical to the navigational success of individuals as without it they will be unable to recognise and recall the environment effectively. Once individuals have started to correctly identify elements they can begin to structure their models (or environmental knowledge) into a meaningful and useful form. Whilst there is little doubt that the physical aspects of an environment play a vital role in people's environmental knowledge, the meanings people attach to objects and spaces are also important. As a result of the process of identifying, structuring and obtaining meaning, the interpretation of a space will vary from person to person. This gives rise to the idea of people conceiving as well as perceiving their space. In essence, they create a place from a space and each person's "place" will be unique.

People should also be able to recognize and recall an environment or objects, in essence

Lynch Concept	Description
Identity	The process of correctly interpreting and identifying various objects or locations within a space.
Structure	The ability to map the spatial to non-spatial aspects of an environment. For example, mapping activities onto where they take place.
Meaning	The process of attaching meanings to objects and locations.

Table 2-1 Three key concepts by Kevin Lynch.

be able to identify its elements (Benyon and Höök, 1997; Harrison and Howards, 1980; Lynch, 1960; Stringer, 1975). Recognition of artefacts permits users to understand the use of these artefacts in the context of the environment, for example, an object such as a door. A door affords certain actions, for instance it can be opened, closed and entered. These range of affordances are commonly understood and most people will should readily understand that they are available (Norman, 1988). The ability to recognise a door even applies if the door has a different appearance or is situated in a varying (cultural) context. Lynch argues that the ability to identify a door is equally based on its physical appearance as well as intrinsic meaning.

In order for people to be able to identify, structure and obtain meaning from an environment they must have the ability to correctly map their activity needs to the environment's functions and spatial structure, through a process known as congruence (Lynch, 1981). This process essentially is the structuring of their environmental knowledge into some stable form. Congruence enables people to know where certain activities can take place. Moreover, the ability to map spatial to non-spatial aspects is dependent upon a range of factors including usage, social patterns and a person's sense of place. This includes a range of perspectives such as the symbolic, cultural, political and biological view of the perceiver (Buttimer, 1980b).

As people navigate within a space they often start to attach subjective feelings (or meanings) to artefacts or areas. Such meanings often appear in the way people describe the environment to others, for example, "the church is full of intimidating images and I don't want to go there" or "I enjoy the path I take to work as I often bump into friends on the way and have a chat". Although these are rather simple examples they do illustrate that the navigational choices made by people are often affected by the meanings they attach to areas or artefacts. Moreover, although meaning is important people also need to know the information they are basing their navigational choices on is reliable (Harper, 1998). For example, if a user of a city guide finds the information inaccurate of biased they may be reluctant to make use of it in future.

Meanings play an important part in the environmental knowledge people possess of both real (Norberg-Schultz, 1971; Rapoport, 1982) and virtual (Shum, 1990) spaces. Norberg -Schultz says that all spaces exist in primarily two dimensions: the space of action and the expressive space. These two dimensions combine to give the feeling of 'being somewhere' (see Figure 2-1), and if either aspect is missing then a person will not feel as if they are part of the space. The space of action is defined as the physical environment and the expressive space is essentially the emotions and meaning attached to objects, locations and activities. This view is backed up by various researchers who have studied the built environment (Broadbent et al., 1980a, Broadbent et al, 1980b; Perziosi, 1979). Moreover, the meaning attached to objects and the subsequent behaviour by end users will vary in accordance with the behaviour of others (Wheeler, 1971) and the social rank of the individual ((Altman and Taylor, 1973) cited in (Canter and Kenny, 1975)). All these researchers have pointed out that a lack of consideration for meaning within an environment will lead to a poor understanding of the activities people are likely to undertake.

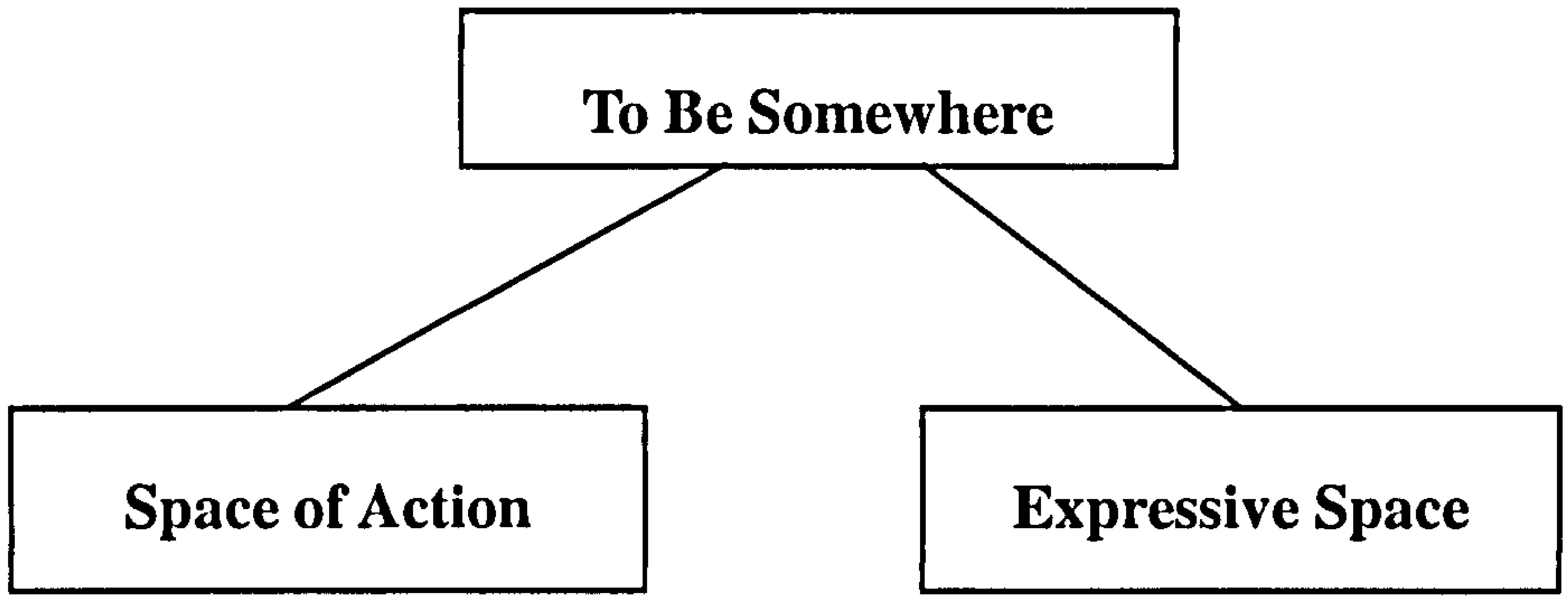


Figure 2-1: The Norberg-Schultz model of space.

As individuals we all behave, interact and socialise in a situated context and as a result Norberg-Schultz suggests a dramaturgical (or theatrical) model of interaction. The dramaturgical model views the actor (navigator) as situated within a stage, which is populated by the setting, other actors and props; the setting being the overall space, for example a shopping mall, the actors being shoppers and the props being objects that are available to purchase. This emphasises the view that all plans, actions and behaviours are carried out within a situated context (Suchman, 1987). The situated actions model views interaction within the environment as an ongoing process, one that will evolve as a person's experience increases. Finally, the dramaturgical model of interaction within electronic spaces is in some ways very similar to one proposed by Laurel (1991) in her book Computers as Theatre.

The various viewpoints of interaction contrast and complement other theories, such as cognitivism. A purely cognitivist view would place little emphasis upon the behaviour of others or the meanings attached to the environment by its users. Moreover, as indicated in the rest of this chapter the cognitive view of an environment is frequently shaped by the meaning, emotions and personal preferences of its users. As a result, to ignore these aspects would remove many of the features that shape the ability of individuals to develop cognitive maps.

2.3 Environmental Knowledge

Environmental knowledge plays a critical role within navigation. The concepts of identity, structure and meaning all have an impact upon the schema developed by individuals, which in turn will affect their navigational behaviours. Several studies of navigation (Devlin, 1976; Hart and Moore, 1973; Siegel and White, 1975) have indicated that individuals have three primary types of environmental model: undifferentiated egocentric, partially co-ordinated and operationally co-ordinated. The undifferentiated egocentric schema consists of people having only route-based knowledge of an environment; they can go from point A to point B, however, they cannot go from B to A as they do not posses an overall view of the environment (Kuipers, 2001). A partially co-ordinated schema results in individuals being able to map an environment by various landmarks, or salient points. An operationally co-ordinated view corresponds to people having a bird's-eye view of the environment and theoretically they should be able to navigate from any point to any other point. These concepts are more commonly referred to as route, landmark, or survey knowledge, respectively. Siegel and White (1975) indicate that people typically navigate initially by the aid of landmarks, then make use of route-based descriptions and finally, as a result, of navigation over a period of time are able to navigate by the use of survey knowledge. This framework is similar to the stages a child uses to navigate within an initially unfamiliar space (Hart and Moore, 1973). However, several theorists (Aginsky, Harris, Rensink & Beumans, 1997; Janzen, Shade, Katz & Hermann, 2001) have argued that such a model of environmental knowledge does not always hold. These alternative theorists typically assert that environmental knowledge is also dependent on age (Heth, Cornell& Alberts, 1997; Kitchen, 1996; Schmitz, 1997), usage patterns (Devlin and Bernstein, 1997; Janzen et al., 2001; Teske, 1986) and gender effects on navigational strategy (Lawton, 1996). Differences were also noted owing to environmental layout (DeJonge, 1963; Evans, Skorpanich, Garling, Bryant & Bresolin, 1984), education (Appleyard, 1970), and ethnic factors; the latter being evident in the use of numbered grid like structures in cities like New York compared with the use of street names in Europe (Hall, 1980) and the naming of junctions rather than streets in Japan.

2.4 Navigational Behaviour

Passini (1984) and Kaplan (1976) provide a background to the basic components of navigation within the built environment. Passini proposes three aspects of navigation: *cognitive modelling* (the mapping of the environment), *decision-making* and *execution.* In addition, Kaplan defined four properties of navigation: *recognition* (knowing location and identity of objects), *prediction* (knowing what happens next), *evaluation* (knowing the potential good or bad aspects of an action) and *action* (knowing what to do next). These aspects are of importance in understanding how to support people in their navigational tasks. For example, there is a need to support decision-making through specific cues (e.g. the design of signs, routes or junctions) to make the environment clear and easy for the navigator. In addition, there is a need to understand which aspects will aid in the construction of environmental knowledge and the recognition of objects. Finally, once people have been able to undertake these actions the environment must aid the process of making judgements on navigational status.

The basic aspects of navigation described by Passini (1984) and Kaplan (1976) concentrate on the generic navigational components of people within the built environment. Both authors focus on what people do when navigating rather than examining the types of navigational behaviour. In addition to these aspects, there is also a need to understand what type of navigational activities people are undertaking.

Although there are several models of navigational behaviour most contain aspects of the following three properties: *object identification* (Benyon and Höök, 1997) which is similar to the concept of *identity* and *structure* (Lynch, 1960); *exploration* where people have no specific tasks; and *wayfinding* (Downs and Stea, 1977) where they have a specific goal.

Wayfinding consists of four attributes: *orientating oneself in the environment*; *choosing the correct route*; *monitoring the route;* and *recognising* that a destination has been reached (Downs and Stea, 1977). The principal aspect of this model is that it does not support a browsing strategy and assumes that the individuals have appropriate route knowledge or can make use of a range of environmental cues that will support them, such as paths, signs and buildings. There is a range of models of navigation and those applicable to electronic spaces are discussed in Chapter 3.

2.5 Physical Environments

The discussion so far has focused upon the mental schema a person holds of their environment, the types of navigational behaviour they undertake and a range of higher level abstract concepts such as existential spaces. In this section, we focus upon specific properties of the built environment that will affect its imagability, legibility and meaning, and the subsequent effect that this has on environmental knowledge and behaviour.

Bentley, Alcock, Murrain, McGlynn and Smith (1985) provide a series of concepts on how to make an environment responsive to the needs of the people undertaking activities within it: *permeability, variety, robustness, visual appropriateness, richness, personalisation and legibility.* These are high-level design concepts rather than specific issues such as the use of colour or layout. As a result, the purpose of these concepts is to alert the designer to issues that should be taken into consideration during the design process.

2.5.1 Permeability

Permeability is one of the critical aspects of navigation and is how easy it is for people to make their way through the environment. Permeability is dependent upon the paths and objects contained within a space and their layout. For example, an environment may have several paths, however several may be blocked by objects and these paths may link districts or areas, hence reducing the permeability of the space. Permeability exists on two levels, initially the physical existence of the paths and secondly the visual appearance given to the paths; because if a path is not visually obvious people may not take it. Permeability is also dependent on a number of environmental factors and behaviours. The first concept is that of public and private spaces and the notion that paths must provide some form of cue as to which is which. In addition to providing these cues they must also provide a link denoting the degree of privacy required by any particular route; this can be provided within the appearance of the route itself and can be enhanced using entrances. Entrances provide an interface between the wider environment and the private space.

2.5.2 Variety

Variety is partially dependent on the permeability of an environment and exists in three main categories: building types and forms, variety of people, and activities. As a result, variety is a complex interplay between uses, forms, people and meanings. Variety is concerned with how a space houses several activities. For example, a shopping mall may contain shops, restaurants and bars. As a result people can carry out several activities such as buying goods, eating food or drinking beer. In contrast, robustness (discussed in section 2.5.5) examines how the use of a space can vary through changes made to it or by how people interact.

In order to design an environment that supports variety, an understanding must be gained by the designer into the types of activities that people may wish to undertake. In a commentary on the semiotics of the built environment, Perziosi (1979) provides an example of variety from the perspective of a shopping mall which contains a variety of shops, bars a cafés. The types of use to which each unit has been put has been determined in part by the relationship between the range of activities people wish to undertake, the locations of the various retail units and also the paths of movement within the mall.

Variety is supported by a range of features such as the inherent block structure of the space and the potential range of uses a space may conceivably have. In designing for variety care also has to be taken that closely positioned spaces are not mutually exclusive. The term mutual exclusion refers to whether spaces in close proximity to one another are socially and functionally compatible. When adding variety to a space cues have to be used to encourage people to make use of the relevant features. Therefore, the variety of options provided should in part be based around the pedestrian flow.

2.5.3 Robustness

The spatial layout and contents of an individual area will change its ability to house a range of activities. Robustness examines the ability of a specific space, for instance a meeting room, to facilitate a number of activities. An example of robustness would be a meeting room which is used by a group of academics. Under normal conditions this room would be used to house traditional academic activities, however, without any changes it can also be used to hold the Christmas party (Benyon and Höök, 1997). This example illustrates that although the social intentions of the academics resulted in a change of room use, the room itself was robust enough to support the new use to which it was being put. Another example by Erickson (1993) illustrates the temporal aspects of robustness. Erickson stated that a busy street contained a walk/don't-walk sign, a crossing point and a newspaper vending machine. Although each provided a physical use, when the 'don't walk' sign was lit people would frequently go over and purchase a newspaper. As a result of this the area around the machine now either acts as a place to quickly read the newspaper and/or converse with other pedestrians. In this example, the use of a street section was affected by a combination of people (their movement patterns and desires), time (whether or not the walk/don't walk sign was lit) and physical aspects. Robustness can be defined as either small or large scale, small scale affecting an individual area such as a room and large scale affecting an entire building.

2.5.4 Visual Appropriateness

Many authors agree that an environment needs a diverse range of visual cues to improve the legibility of the objects and spaces (Abu-Ghazzeh, 1996; Evans, Fellows, Zorb & Doty, 1980; Lynch, 1960). Visual appropriateness examines how the provision of appropriate cues can support legibility, variety and robustness. Visual appropriateness is vital if individuals are to correctly interpret the meaning of the environment and be able to interact effectively. An example of poor visual appropriateness is where the inside of a building uses almost identical colour and forms throughout making it difficult for people to identify different objects or spaces and as a result, they experience navigational problems. In contrast where buildings are clearly differentiated by colour or other means this improves environmental legibility and should therefore increase the navigability of the environment.

2.5.5 Richness

The elements described so far have primarily focused on the non-emotional properties of the environment that can improve its responsiveness to the needs of its users. In contrast richness focuses on how emotional aspects can be used to encourage users to enjoy the space. Richness depends on range of senses, emotion, smell, hearing and touch. Bentley and Alcock et al. (1985) argue that a range of cues can be used to enhance richness including the use of visual contrasts between forms, viewing distance, numbers of people and length of time something is in view. The latter is in many ways similar to the idea of movement through space and time and how this affects a user's behaviour and environmental model (Bacon, 1974). As a result, designers of an environment need to give careful consideration as from where an object or space can be viewed for, how long it can be viewed and who can view it.

2.5.6 Personalisation

Personalisation is the ability of the environment to be customised on a large or small scale. Personalisation aids in environmental robustness and legibility as people can change the purpose of a space and perhaps enhance its image (legibility). There are two primary types of personalisation, practical facilities and image. The former deals with adding or removing functional features of the environment whereas image is concerned with changing or altering the appearance. In electronic social spaces (such as collaborative environments) personalisation exists on two main levels: single user only (i.e. private) and those effecting groups of users (i.e. public). Consideration needs to be given to the appropriate levels of personalisation. Public personalisation can be a way for individuals to express themselves to a wider audience.

2.5.7 Legibility

The concept of legibility has been discussed and defined by a range of authors (Aragong and Arrendondo, 1985; Bentley at al., 1985; Holohan and Sorensen, 1985; Lynch, 1960). The legibility of an environment depends upon two critical factors, its physical form and the activity patterns of those using it. A legible environment will permit individuals to recognise parts of it as well as structure them into a coherent mental map. A summary of the main components as initially defined by Lynch (1960) is provided.

- Nodes. Strategic foci within an environment which are found within paths or at junctions within environments.
- Landmarks.Salient points within an environment that can be used by people to aid them in navigation.
- Paths. Movement channels within the environment such as walkways, roads or motorways.
- Districts. Areas that consist in some way of related features, for example, the banking sector of a city or China Town in London.
- Edges. Physical or imaginary boundarys that exist between two or more districts.

2.5.7.1 Paths of Movement

Paths are a critical aspect of the built environment as they provide channels of movement and as a result aid in the creation of mental maps (Appleyard, 1970; Devlin 1976; Kuipers 2001; Lynch, 1960). Research has found that path structures can typically constitute up to 90% of the environment that a person recalls and are among the first environmental features learned. Paths can change the meaning of areas and may provide a means of improving accessibility to locations. In addition the actual recall of paths is dependent upon a range of factors including the physical properties of the path as well as range of other aspects non-physical aspects (Appleyard, 1970; Davies and Herbert, 1993; Harrison and Howards, 1980; Lynch, 1960; Kuipers, 2000; Stea, 1974). Social interaction plays an important part in the choice of path and people have often chosen their routes based on the potential to meet other people. Meanings also have an impact on where people go, and people will often try to avoid areas which they don't like. Other aspects include activity patterns, e.g. a mother driving her child to school may have a regular route which is based on safety and journey time, personal preferences (e.g. scenery) and intentions (e.g. going to visit a friend afterwards).

Paths support the movement through space over a given time period (Bacon, 1974; Ching, 1996). As individuals navigate through the environment using explicit or implicit path structures, various features of the environment will become apparent to them. This gives rise to the experiential concept of path (Norberg-Schultz, 1971), in essence "we experience space in relation to where we have been and where we are intending on going" (Ching, 1996, p228). Therefore, the concept of 'path' is not only related to the physical aspects of the environment but also the meanings and other subjective responses that people have had or are likely to experience.

As well as supporting the basic movement through the environment, paths can also be used to channel people in specific directions depending on their roles (Kishnani, 1999) or to indicate different purposes when used with various legibility techniques (Venemans, 1999). For example, in Stanstead airport different paths are provided for those boarding aircraft, airport staff and visitors to the airport (Kishnani, 1999).

The nature of paths within the overall context of the environment will affect not only the behaviour of the people using it but also the mental maps they create. At a basic level recall is dependent upon the direction of the path, how frequently it is used and the purpose it contains for those who use it. These basic issues are further reinforced and expanded upon by a range of other authors (Buttimer, 1980a; Stea, 1974). For example, the purpose a path has for its end user may be the product of a range of factors, such as field of contact with others, activities and travel patterns. Examples of these are provided by Stea, who found typical paths people remember have destinations which include a neighbourhood centre, location of three best friends and place of work. Therefore, the decision to navigate along a path is a product of social, functional and environmental considerations. This, Buttimer argues, gives rise to the main considerations that effect path use such as whether the task is voluntary or involuntary e.g. visiting a friend or going to work. As a result of these and factors already mentioned Buttimer indicates that people will ultimately build up a range of paths that they use based on preferred places, interaction spaces, safe and dangerous spaces and finally frequented and avoided paths.

In addition to the social factors, Harrison and Howards (1980) indicated that although presentational aspects of paths are important, the level of recall was dependent on the meanings associated by the traveller to aspects areas of the path. Moreover, the subjective positive or negative ratings of paths typically varied in accordance with a number of factors. Typically, highly rated items whether positive or negative aspects tended to arise because of their location. In addition, many users' recollections of negative aspects were correlated to the ambience/atmosphere generated by the path or its surrounding areas. This would suggest that the articulation of spaces (infusing of emotion) as highlighted by Bacon (1974) plays an important role in aiding environmental legibility. The process of articulating an environment involves adding features that convey certain emotions or feelings.

Paths have also been found to act as points towards which people seek to navigate in both the built (Elliot and Leask, 1982) and natural (Whitaker and Cuglock-Knapp, 1992; Whitaker, 1996) environment. A typical strategy adopted by city navigators is known as 'divide and conquer'. This is where they initially seek to navigate towards a main road, with the aim that this will be connected with the minor road they are looking for. Elliot and Leask also found that the search strategy of identifying the major road initially depends on its presentation (form) and colour, as people typically look for what resembles their conceptualisation of a main road. As a result, they rely less heavily on the signs or other labelling features that the road contains.

Paths may also possess varying degrees of importance or symbolic meaning for their users (Norberg-Schultz, 1971), for example, where a path goes above or below normal height it may also imply some more important emotional dimension. Further to this, where a path has clear start and end points it will have a stronger identity. In addition, Norberg-Shultz indicates that although it is easy to assume that people will wish to take the shortest path, this is not always the case and they may seek to take one that has an emotional meaning to them. This gives rise to the concept of hedological space ((Lewin, 1966) cited in (Norberg-Schultz, 1971)), which draws upon the ideas from hedonism. In essence, the navigator chooses a path based on the pleasure he or she will experience rather than practicality.

In order for a path to provide clear guidance to the navigators on where they are going and to articulate any important meanings it must contain several critical elements. These elements are: the approach, entrance, configuration, relationship to other spaces, and physical form (Ching, 1996) (see Figure 2-2).

- Approach. The navigators obtain a distant view of the building, which is their ultimate destination.

- Entrance. The physical way of entering the building from outside to inside. Entrances provide a critical aspect of any build environment, they initially provide a feeling of going from here to there, or arriving at the destination. They can also act as a threshold between two places thereby reinforcing moving from one place to another. A clearly defined entrance will therefore not only indicate to the navigators they are entering a new space but also reinforce the difference between the new space and those that proceed it.

- Configuration of path. Path configuration plays an important part in the navigational process. For example, when navigating a route an intersecting path creates a decision point for the navigators. In addition to intersecting paths, there are also a variety of path layouts that will affect the users' perceptions of the environment. This will ultimately affect their ability to navigate within the space. The prominence given to the paths (i.e. are they a primary or secondary means of getting to a given place) and any entrances placed along the path impact upon the navigation decisions people take.

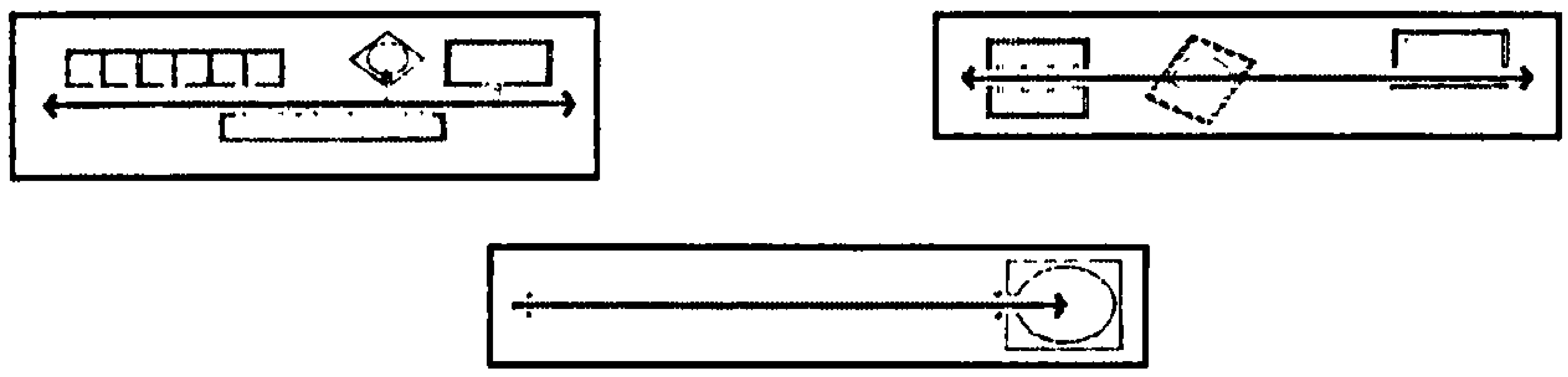


Figure 2-2: Ching's Three types of path. Pass-by, pass-through and Terminate.

- Path-Space relationship. Paths provide a range of relationships to the spaces they encounter, which is dependent on the interface between the path and the space. These interfaces, or relationships consist of *pass by*, *pass through* and *terminate* (Figure 2-2). Pass by spaces allow the integrity of a space to be maintained, as the path does not physically enter it. A typical example is a corridor that contains glass windows between it and the surrounding rooms. Pass by spaces have the advantage of preserving the meaning and the integrity of the spaces they pass by while at the same time providing a flexible path configuration. A pass by space links mediating or related spaces. Pass through spaces intersect with the space, for example, a pathway within a room. Terminate spaces provide a focus for the route as the path ends at a specified point and may be used to establish a sense of path and any aspects of functional or symbolic importance. Lynch (1960) suggests that a strong termination point improves environmental legibility. A path may also act as either a participation or orbit space (Buttimer, 1980a). A participation space (or path) is one where an activity occurs such as using a bank auto-teller. Conversely an orbit space only provides a means of movement while perhaps allowing the person to view the surrounding spaces but not interact with objects or other people in them.

- Form of Circulation Spaces. The final aspect of movement spaces (or paths) is the form the circulation space takes. The form provides a critical aspect and may manifest itself in a range of ways to support aspects such as boundaries, relationships between spaces and entrances. Once the form has been decided the level of enclosure of the space in relation to others provides another important cue. For example, an enclosed glass circulation space in a gallery prevents access to the exhibits thereby enforcing a social rule of not touching them, while also implying the exhibits are of some value. A one-sided movement system gives another cue by providing a relationship to the area on which it opens to and a demarcation from the one that is closed off. An open-on-both-sides movement system suggests a greater degree of freedom and stronger links to the spaces it intersects.

The configuration of path plays an important part in shaping the navigator's perception of the surrounding places. Ching suggests that paths influence an individual's behaviour, for example, it may encourage the person to stop, walk or communicate with others. The path can also act to reinforce the surrounding spatial layout and in some cases it may contrast with the layout, thereby causing a visual counterpoint within the space. In order to provide such cues there are a range of path layouts:

- Linear. A simple linear structure provides a complementary way of articulating a series of linear spaces. The precise configuration of a linear path can vary.

- Spiral. Spiral paths are single and continuous in nature and provide a central point.

- Radial. The path emanates from a central point with various legs extending. In common with radial space configurations, this type of path can be used to emphasise or de-emphasise the central point depending on the forms used within the spaces and the path.

- Network. Network path structures provide a method of connecting distant points within the space.

- Composite. A composite path is one which combines aspects of all those previously mentioned.

Although paths are dominant features, they rely largely on supporting forms such as buildings, nodes and landmarks. As a result of this, careful consideration has to be given as to the path-space relationships and configuration (e.g. linear, network, or radial etc.). From an environmental knowledge perspective, it should be clear that paths help in the development of route knowledge and have an important impact on the generation of landmark and survey knowledge. The latter is evidenced by the strong relationship between path features and their predominance in the mental maps of individuals. From the perspective of different navigational strategies employed, paths clearly support wayfinding and may help during exploration or other navigational activities.

2.5.7.2 Nodes

Nodes are strategic foci within an environment (Lynch, 1960). They are found within paths or at junctions and provide points for people to take navigational decisions. They can exist in various forms, for example, a building, crossroads or marker. The Boston study carried out by Lynch indicated that nodes are a critical aspect of the environment for many people and when people talk about them they are typically break points along a route or used as junctions. Lynch also noted that nodes typically prompted people to heighten their attention in anticipation of having to make some form of navigational decision either manually (Passini, 2000), or when automated route guidance systems are used. The study also appeared to indicate that nodes with strong physical properties were more likely to be associated with emotional or functional aspects.

Nodes provide a critical aspect of the environment owing to the fact that they aid in navigation, alter emotional feeling (e.g. Red Square, Russia) and may have a functional relevance to those interacting with them. Lynch (1960) suggests that nodes exist in two forms (as is also the case with districts); they are either introvert (drawing people into the node) or extrovert (radiating outwards). In addition, some consideration needs to be given to other aspects affecting the number, design and placement of nodes. Bentley et al. (1985) provide three aspects of deciding on node design. Initially, prominence should be given to those nodes that contain junctions as they provide an important functional role. The second attribute to be considered is the activities in the adjacent buildings and when these are of greater public relevance the node should be emphasised. Finally, the third criterion indicates that the overall emphasis provided to the node should be dependent upon its relationship to the surroundings and it's relative importance.

2.5.7.3 Landmarks, Anchor Points and Reference Points

Landmarks, anchor points and reference points are clearly distinct singular objects that provide navigational cues (Couclelis, Golledge, Gale & Tobler, 1987; Sadalla, Burroughs & Staplin, 1980). They provide a clear figure/ground contrast i.e. they are easily distinguishable from the surrounding features and are visible from many positions or locations. In addition, anchor and reference points exist. In many ways, these can be quite similar to landmarks, however they are typically not as distinct and are chosen based on a person's preferences. Couclelis et al. (1987) suggests three properties that identify anchor points: properties intrinsic to the object, relational spatial properties and relational non-spatial properties. Similar properties are also shared by reference points, however Sadalla and Burroughs et al. (1980) indicate that a reference point contains features which indicate to the navigator that a navigational decision must be made.

In relation to navigational models, the use of landmarks is assumed to be the first stage in the process of learning about an environment. Sigel and White (1975) suggest that individuals initially navigate within a new environment by moving between landmarks. Additionally, the use of landmarks and nodes may also help in gaining route knowledge (Garling, Book & Engersen, 1982) but there is some discussion as to whether this is actually the case (Evans et al., 1984).

Landmarks fall into two broad categories, distant and local. Distant landmarks are visible from many surrounding areas and are frequently used by those unfamiliar with a town or city to aid in the navigation process (Lynch, 1960; Devlin and Bernstein, 1997). This would appear to backup the idea of people gaining landmark, followed by route then survey knowledge (Siegel and White, 1975). In contrast, local landmarks tend to be more frequently remembered by those who are more familiar with an environment and encompass a range of environmental features. Local landmarks also appear to be partially remembered in relation to other sensory elements such as sound and smell, also by meaning, significance and function.

The aesthetics or the purpose of a landmark has an impact on the accuracy of distance judgements (Smith, 1984). This is referred to by Smith as the pleasingness of the landmark; for example, people were more accurate when remembering pleasant landmarks (e.g. bars or boutiques). This leads to the idea that the distance estimate is affected by the attention given to the landmark and that this will in turn effect the ease of its retrieval and storage (Smith, 1984).

While it is clear that landmarks are part of any environment, there is some difficulty in defining exactly what constitutes a landmark. For example younger children have used movable objects such as dogs and bins as landmarks (Heth et al., 1997). Other differences have also arisen in relation to the use of landmarks as females appear to suffer from greater fear and anxiety (Devlin and Bernstein, 1997; Schmitz, 1997) and consequently rely more heavily on landmarks (Kitchen, 1996).

2.5.7.4 Districts

Several authors have documented the prominence that districts have within the mental models of individuals (Beck and Wood, 1976; Ching, 1996; Lynch, 1960; Norberg-Schultz, 1971; Sorkin, 1993). Districts are a combination of the other environmental features such as landmarks, paths, edges and nodes. Lynch, in common with other researchers, suggests that districts are one of the key aspects of environmental image. Although Sorkin refers to "places" his definition is similar to the Lynchian description of districts. According to Sorkin, a district (or place) is "a publicly perceptible and spatially distinct portion of the city which exhibits coherence" (Sorkin, 1993, p62). In order to exhibit some coherence a district must contain some common features including: textures, space, form, detail, symbols, building type, use, activity, group of inhabitants (e.g. ethnic or social), or topography. Districts are a critical aspect of any town or city. As well as sharing a range of common properties, they are frequently supported by the use of signage or marketing tools. Finke (1994) provides a number of sign examples of areas within the US, which have utilised district signification. Moreover, Lynch suggests that it is easy to gain orientation in Los Angeles, owing to the range of well-defined characteristics within the districts. The following discussion will draw together some aspects of the design of spaces with that of districts, although there are clearly some differences between the two.

Organisation (or topology) is one of the critical aspects, that defines a district. Ching (1996) provides a range of common layouts such as centralised, linear, radial, clustered and grid (see Figures 2.3a to 2.3e). Each of these suggests a range of meanings and in turn may provide a way to increase the legibility of an environment.

- Centralised. Centralised forms provide a degree of emphasis with respect to the element at their centre. Centralisation can be used to express a range of meanings: the element is more important than the non-centralised components; the centralised component is the key aspect of the surrounding components; the element is free standing and thereby is not related to other objects; or more emotional meanings such as that the form is sacred or honorific.

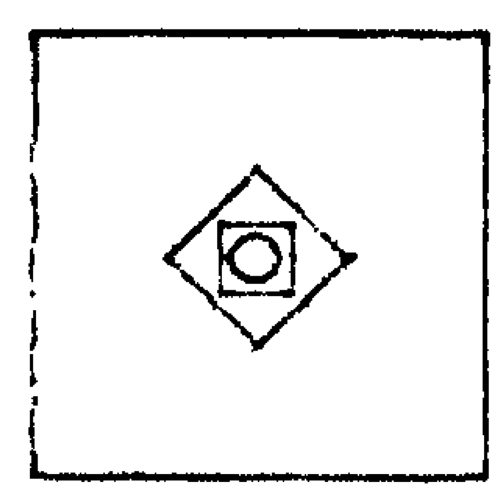


Figure 2-3a: A centralised grouping.

- Linear. When districts are linear in nature they can be used to provide a range of meanings. Typically, a linear form contains a sense of repetition that is highlighted by placing identical or similar objects along the axis. Linear arrangements can also be used to highlight the significant difference of one form in relation to another by placing an inconsistent object within the linear arrangement. The latter method can be used as means of articulating entrances to other forms e.g. a wall contains an entrance using a different form. The sudden change and use of an appropriate form will serve to highlight its purpose as an entrance. Linear forms can be used to provide explicit or implicit movement cues, a typical example being where two parallel rows of statues are placed on a lawn, the gap between the statues suggests a path that people can follow.

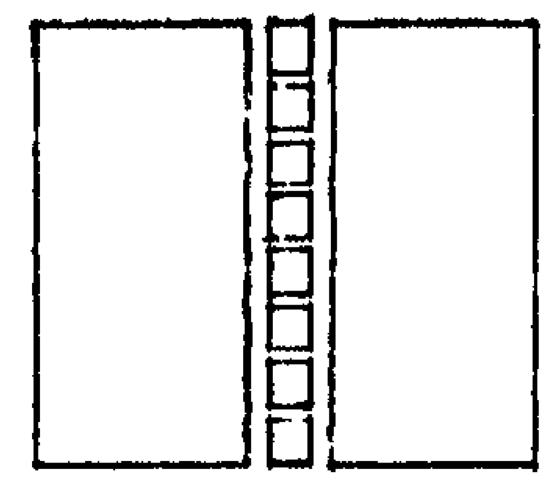


Figure 2-3b. A linear grouping.

- Radial. Radial forms combine aspects of centralisation and linearity to suggest alternative meanings. The radial form consists of a central portion and several linear legs, which, depending on the methods used to articulate the centralised part, can either suggest that it is dominant or subservient to the surrounding legs. The legs contained within the radial forms can then be used as links between other radial forms.

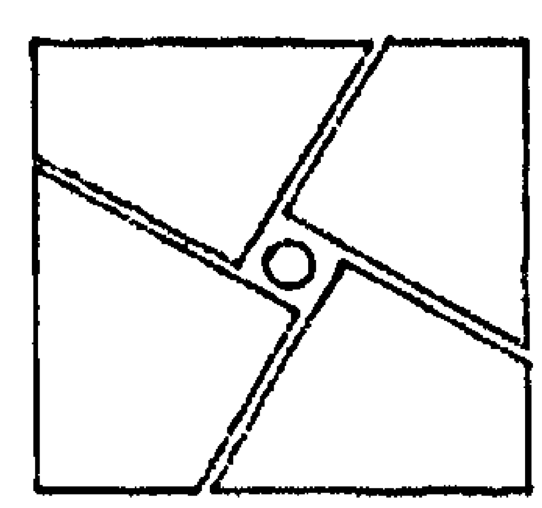


Figure 2-3c: A radial grouping.

- Clustered forms express relationships based on proximity and articulation. For example, objects in cluster X share a higher degree of relationship to cluster Y than to cluster Z. Clustering can also be carried out on a hierarchical basis, forming group and sub-groups of related clustered forms.

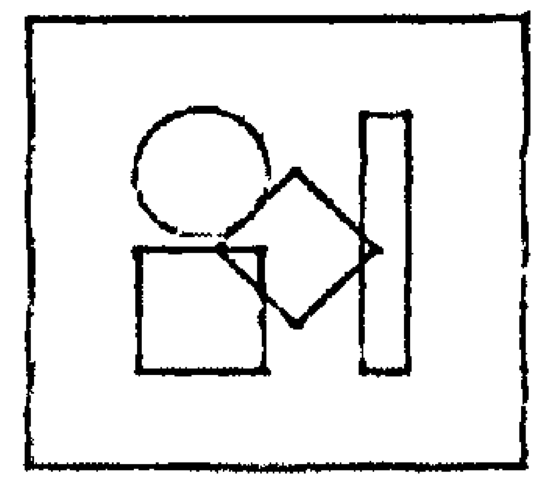


Figure 2-3d: A clustered grouping.

- Grid. In contrast with clustered forms, grid layouts cannot be hierarchical in nature. Grids provide relationships through the repetitive and regular structure they provide.

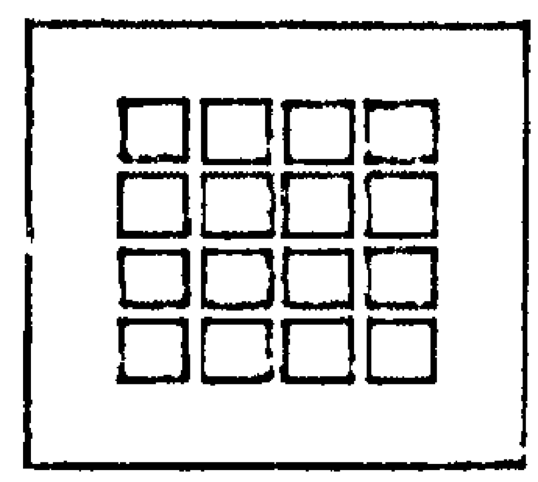


Figure 2-3e: A grid grouping.

In addition to the layout of districts or spaces listed previously, the relationship between spaces exists on four further dimensions (Ching, 1996). Each dimension provides a different spatial experience and hence meaning, see Figure 2-4a to 2.4d.

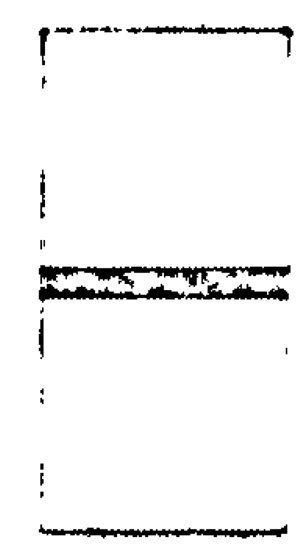
- Space within space. A space within a space exists when one larger zone (or form) encompasses another.

2-4a: A space within a space.

- Interlocking spaces. Where two spaces connect to one another at a common point. This results in a suggestion of overlap, or shared meaning between the spaces.

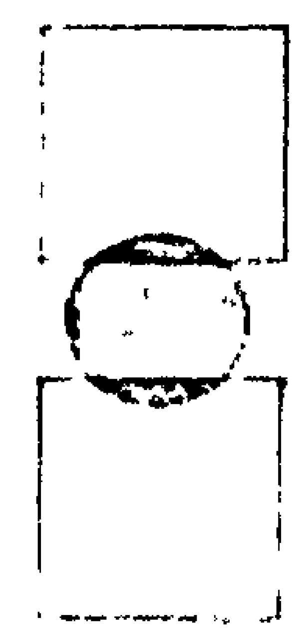
2-4b: An interlocking space.

- Adjacent spaces. Two spaces are apart, however they share a common plane; the common plane acts as a binding point but also serves to separate them.



2-4c: Adjacent spaces.

- Spaces linked by common space. Two aspects that are separated by distance can be linked via a common intermediate space. The intermediate space provides a means of suggesting a close or distant link between the two spaces it joins; in addition the intermediate space can also act as dominant space in relation to the other two.



2-4d: A central common space.

2.5.7.5 Edges

Lynch argues that environmental legibility is further enhanced by the existence of edges. Edges provide boundaries between districts; an edge can also act as a circulation system such as path or motorway. Typical examples of edges include motorways, rivers or a sudden change in architectural style between two different districts. An edge takes its existence from its continuity and visibility in relation to the districts it separates. It may be a pronounced difference such as a river or more subtle in the form of signage which serves to separate two districts.

Edges act as a means to aid in the creation of an image of the environment. One study in relation to virtual environments (Collie and Reid, 1998) found that the ability of people to correctly point in the direction of an object or region boundaries exist. Moreover, this is regardless of whether the edges are visible. In this study, people still experienced directional pointing accuracy errors between rooms even when there was no physical boundary between themselves and the target object.

2.6 Signs

Signs are one of the main aspects used within the built environment and provide a range of cues to support navigation and other social aspects as well as reduce navigational problems for new and experienced users of the space (Abu-Ghazzeh, 1996; Abu-Ghazzeh 1997; Bittner, 1992; Finke, 1994; Follis and Hammer, 1979; Kishnani, 1999; Loomis and Parsons, 1979; Passini, 1996; Pollet and Haskell, 1979; Spencer and Reynolds, 1977). Signs have played a critical role in the environment within many cities, university campuses, transit systems, banks, city halls, and libraries, and have been used for a variety of purposes by car drivers and pedestrians. However, signs are part of the overall navigation system and they complement the whole environment, which in itself is a wayfinding system. Typical examples include the use of directional cues to attract people to specific areas of a city or feature, or to augment their navigational decision process. In a study of US cities by Finke it was found that in Knoxville specific cues were used to direct people into downtown neighbourhoods with the aim of increasing the number of people and subsequent usage of public and commercial facilities. Moreover, The University of Maryland at Baltimore attempted to infuse additional character into its campus by commissioning a themed range of graphically pleasing and perceptually stimulating designs. This concept was further advanced by Ang, Loeng and Lin (1997), who indicated that aesthetic and spatial layout attributes have an effect on the pleasure (favourable feelings) and arousal (level of excitement) experienced by users of banking facilities and may subsequently affect their approach-avoidance behaviour towards objects or locations (Bittner, 1992). Consequently, assuming an environment employs an appropriate signage strategy it should result in an increased usage of its features and this may aid in the process of deriving meanings from the environment. Carr ((1978)cited by (Abu-Ghazzeh, 1997)) argues that signs and other aesthetic attributes can improve the image of the environment. DeJonge and Passini (DeJonge, 1963; Passini, 1996; Passini, 1999; Passini, 2000) demonstrate that wayfinding is more accurate when signs are readily and accurately perceived. Therefore, signs are not only a method of providing directional cues but are also an aid in the identity of areas within cities, neighbourhoods or other complexes.

2.6.1 Classes of Signs

An initial classification of signs results in three categories: informational (providing information on objects, areas, users and activities), directional (providing route or survey information), warning and reassurance (providing information on the actual or potential actions). In all cases, the signs can make use of dynamic and/or time-dependent information, typical examples are making people aware of available routes or information on book classifications in a library (Daniel, 1979). Within the categories already highlighted there exists a range of other sign types, for example, instructional, location, identity, advertising signs (Abu-Ghazzeh, 1997) and building signs. According to various authors (Ang et al., 1997; Selfridge, 1979) instructional signs provide 'how-to' information to people, for example, instructions on how to use a cash point. Location signs (IOS, 1979) can exist within directional or informational sign types and provide location information; these are somewhat similar to identity signs, which identify individual objects. In a study by Abu-Ghazzeh (1997) of signage in Amman, Jordan, it was noted two types of information signs were used, these were advertising (e.g. a bill board advertising a specific product) or building signs. The last category of signs is placed on the exterior of a building and indicates the name or type of business. Advertising or building signs can exist alongside the basic types of sign and within a range of contexts. A typical example would be signs outside a library providing directional information, then the placing of an informational/directional sign at the library entrance to indicate arrival and to reassure the users they are at the right location.

2.6.1.1 Directional Signs

Directional signs provide a range of cues to aid individuals in travelling a specific route (Signs, 1979), orienting themselves within the whole environment (Finke, 1994) or a direction (not via a specific route) to a particular destination. An example of the latter may be a sign indicating that a Cathedral is in a town which points in the general direction but does not provide specific route information, for example, "Cathedral 500 metres West". Sign hierarchies support the provision of specific route information. A typical example is in Madison, Wisconsin where the sign hierarchy provides an indication of the destination (initial encounter). The signs also provide other navigational options, such as when the decision has to be taken to join a specific route (transition) and in common with Downs and Stea a clear indication of arrival to reassure the navigator. The sign hierarchies contained within the Madison traffic system use a range of other cues to aid in the driver's orientation by labelling each route with a distinct icon and colour. As a result, the driver is able to recognise the route without having to spend a significant amount of time reading the signs. Although sign hierarchies are useful for navigation, care should be taken to ensure that the navigator remains orientated within the whole environment and not only that particular route. As well as supporting specific routes the signs also have to consider the types of routes or destinations they are alerting navigators to. Therefore, the signs should also indicate whether outcome is a major or minor destination. Both Selfridge (1979) and the Institute of Signs (1979) argue that this applies equally to internal as well as external environments. The precise definition of major/minor will depend upon the nature of the environment and the important places or tasks to be conducted.

Butler, Aquino, Hissong and Scott (1993) suggest that directional sign systems need to follow certain other conventions. These are that they should use numbers for consecutive areas, rather than words or letters. In addition, they should name and number areas of space to facilitate wayfinding. In the case of the latter, this may overlap with the provision of informational signs.

2.6.1.2 Informational Signs

There are also a range of potential information signs including instructional, locational, identity, advertising/public relations (Marks, 1979) and building signs. The range of informational signs usually results in them containing combinations of different factors and as a result complimenting existing directional signs. Typical uses of information signs include the labelling of a building or type of business, provision of event information, labelling of an area inside a building (e.g. an issue desk in a library), or to assist in navigation within a transportation system to clearly identify areas of cities. As a result, ranges of techniques have been used to provide information to navigators. For example, Finke (1994) found that in Cincinnati and Knoxville information points were erected in streets providing a stopping-off point for people to relax in what was otherwise a busy environment. The City of Cincinnati's informational signs included wayfinding maps, building labels and general information. In order to aid in orientation various information points were placed around the city consisting of the wayfinding maps as well as pictures of nearby locations, the aim was to allow for easier recognition of the landmarks. Although signs may be used to provide specific information, they can also be used to aid in the environmental vitality and to provide orientation cues.

Abu-Ghazzeh (1997) argues that implementing informational signs requires careful consideration of a range of issues including consistency, quality and the number of signs. Additionally there is a need to consider the type of environment in which the sign is being used and the importance of the item being signed. For example, in the external environment major buildings should be more obviously signed, similarly, in an internal environment, it is more beneficial to sign major areas, for example, the information desk in a library as opposed to individual patron desks.

2.6.1.3 Warning and Reassurance Signs

Warning and reassurance signs complement the informational signs by providing specific information. In the built environment, these may include hazards, warnings about impending crossing points or dynamic information indicating that a course of action may be fatal. Reassurance signs provide feedback to people to indicate that their actions have been successful.

2.6.2 Design and Placement Issues

The design and placement of signs is critical to their overall success, regardless of which group they fall under. Abu-Ghazzeh (1997) defines three high level variables of environmental and sign design, which are essential for navigation. These are: *identification* (enhances ability to identify space), *differentiation* (sign types are clearly differentiated in some way) and *distinctiveness* (the signs are distinct from the environment). He concludes that by providing cues that emphasise perceptual variables the information presented in the signs can enhance environmental learning. As a subset of these categories, two further issues arise: *legibility* (the ability to differentiate the characters or symbols on the sign) and r*eadability* (the ability to correctly interpret the content of the sign) (Wechsler, 1979). As signs are beneficial in allowing navigators to understand the identity and structure of the environment, Abu-ghazzeh (1997) argues that they should complement the underlying design, layout (including decision points) and functional importance of the space. Typical methods of doing this involve using specific colours and icons to represent different objects or locations. In the latter case libraries have used colour coded informational signs that correspond to the colours used in different areas (Downs, 1979; Selfridge, 1979) this provides a clear link between the signs and the environment therefore helping people to identify where they are located. The identification and readability of signs and spaces is further enhanced by consistency of layout, size, wording and colour for similar sign types while making use of inconsistency to aid in identification of different sign types. Dewar (1999) provides a range of guidelines covering these issues as well as general legibility issues of the symbols contained within signs. The readability of signs is further enhanced by a number of critical aspects such as minimising the crowding of signs and the use of clear, short and simple language. The third aspect, distinctiveness, implies that the sign system should be separable from the environment and visible from a range of angles while complementing exiting architectural styles. An example of these aspects of distinctiveness can be found in Philadelphia (Finke, 1994) where the sign systems were designed and placed to not only complement the environment but also to be visible from a variety of positions. Finally, it is often advantageous to design signs in a way which is at least partially consistent with signs found in other cities.

Positioning plays an important role in the effectiveness of directional signs (Daniel, 1979; Downs, 1979; Loomis and Parsons, 1979; Selfridge, 1979) with the key aspect being that the signs should be positioned at decision points and at the start of a journey (Passini, 2000). Selfridge provides a range of possible decision points including entrances, exits, intersections, stairs and elevators. Moreover, Passini argues that if directional signs are not appropriately placed they will simply be ignored. Although these issues reflect on directional signs, in many ways they apply to other sign types as well.

2.6.3 Problems with Signs

Signs provide an important navigation aid, however they do present some interesting problems. One of the main aspects of concern is that signs in themselves may increase the amount of information given to the users while at the same time causing them to experience information overload. This is because people typically have a limited short-term memory (Miller, 1956) and that under stressful situations they will seek to filter out non-core information in a process is known as perceptual narrowing. Even under non-stressful situations it has been observed that people attempt to reduce the amount of information they use or view (Downs and Stea, 1977; Lynch, 1960; Rapoport, 1982).

In conclusion, sign systems represent one of the major tools for aiding in navigation and appear to aid in increasing the use of services and the ambience of an area. However, as sign systems are integrated with the whole environment there is a need to understand the range of users, appropriate number of signs, environmental appearance, major and minor destinations (or locations) and objectives of the providers (e.g. aiming to increase usage of certain facilities). Assuming the sign system is well designed it should be easily recognisable and allow its users to follow it with confidence.

2.7 Conclusions

This chapter has provided a review of several key areas of literature in relation to the design, navigation and subsequent meaning obtained of real world environments. Navigation, regardless of type (e.g. exploration, wayfinding, etc.) is a complex task, which depends on a range of environmental cues, for example, forms, spatial layouts and signs. In addition, aspects such as patterns of use, meaning, social and cultural and past experiences all play a part in the navigational strategy and the use and construction of environmental knowledge.

The review of literature within this chapter has shown that no one theoretical foundation appears to provide an answer as to why people navigate using their chosen strategies. While environmental cognition does appear to provide information on navigational problems, cognitive maps, individual differences and common navigational behaviours (e.g. wayfinding) it ignores several aspects such as meaning, social interaction and past experiences. As a result, an experientialist viewpoint based around the ideas of environmental cognition and legibility would appear to provide a greater degree of understanding of the navigational behaviour undertaken by people.

In conclusion, this chapter has examined a range of properties, behaviours and underlying models of navigation in the built environment from a largely experientialist viewpoint. This examination leads to a number of areas that are important to the design of the built environment as well as to electronic spaces. One of the critical aspects is mapping a user's conceptual view to the underlying physical structures. Clearly, this is a complex task and as a result consists of a range of key points, namely the examination of a range of physical attributes such as nodes, landmarks, paths, districts and edges. However, merely placing these in an environment without an understanding as to how this will affect user navigational behaviour may not lead to the optimum level of user experience and as a result may impact on navigational performance. The aim has been to encompass these core concepts but also place them in the context of the various design issues that will have an impact upon users' navigational behaviour. These aspects range from how to differentiate spaces, promote user experience and provide clear articulation of function or content. Two critical aspects are how the social aspects as well as any underlying meanings a space possesses will shape a person's behaviour. Although the environment itself may provide sufficient cues. There may also a need to provide navigational guidance through the use of signs and other supporting structures. The design, placement and use of signs also requires important consideration. One of the principal aspects to understand is that any sign system will have a substantial effect upon navigational behaviour. As a result, there is a need to understand how the various sign types, e.g. directional, informational and warning and reassurance can be best implemented. Typical examples include using directional signs to support specific routes or paths within the environment, or placing informational signs to define and articulate spaces.

Many of these concepts are quite abstract, however the underlying themes, ideas and viewpoints provide an insight into the way in which spaces can be designed. Using the aspects highlighted as a means of designing and evaluating electronic spaces is discussed in more detail in Chapters 3 through 6. However, it is clear from the discussion within this chapter that navigation in any type of space requires consideration of a range of aspects such as meanings, cues and potential behaviours. If these aspects are not taken into account it is likely that the navigational experience for users will not be optimal. Chapter 4 provides an overview of guidelines that were developed specifically to cover the core issues.

The diagrams of spatial layouts and their descriptions are from or based on the work of Ching and are contained in the book Ching, F. D. (1996). Architecture: Form, Space and Order, Van Nostrand Reinhold.

Chapter 3

Electronic Environments

This chapter presents a review of the literature in relation to navigation within 2D and 3D electronic environments. It clearly indicates that there is a link between the underlying concept of navigation and how people behave within an electronic environment. Moreover, it indicates that existing usability practice largely ignores several aspects of navigation.

3.1 Introduction

The previous chapter discussed navigation within the built environment; in contrast, this chapter examines the concept of navigation within electronic spaces. The discussion focuses primarily upon the relevancy of the navigational metaphor and indicates that people think in navigational terms when using and describing environments to others, that they experience navigational problems and that it is possible to observe behaviours that are similar to those encountered in the built environment. The chapter concludes that although there have been some studies of navigational behaviour in 2D and 3D electronic environments, to date the studies have been too restrictive or have used environments with no real purpose. In addition, existing usability methods and research have not provided significant guidance on navigational issues, in particular with regard to support for different navigational modes.

The following chapter will first explore the navigational paradigm from the perspective of the behaviour, models and problems experienced by users of electronic spaces. Secondly, the chapter will explore current usability practice and concepts from the perspective of 2D and 3D environments.

3.2 Navigational Metaphors, Behaviours and Problems

Although navigation is clearly a problem for users of electronic spaces, the relevancy of the navigational metaphor has been questioned by Stanton (1998), who said that it is not a beneficial way of thinking about usability. However, in contrast with Stanton, a number of theorists have drawn attention to the importance of architectural and spatial metaphors within user interface design (Benyon and Höök, 1997; Benyon, 1998; Dieberger and Tromp, 1993; Erickson, 1993; Lootsma and Rijken, 1998). Its relevancy is further enhanced by research into user behaviour within hypertext, traditional graphical user interfaces, and specialist environments where findings have indicated that people do use spatial metaphors in constructing mental models and to describe environments to others (both aspects are discussed later). This thesis and the work of others such as Gentner and Nielsen (1996) and Condon (1995) argues that while metaphors are valuable they should not be used in an excessive or inappropriate manor.

One area where the navigational metaphor has been of particular relevance is in the design of usable hypermedia systems. The predominant (perhaps naïve) view is that hypermedia systems are easier to navigate and learn from than linear documents. However, research by McDonald and Stevenson (1996) and Whalley (1993) indicates that this assumption does not hold. For example, McDonald and Stevenson found that people often estimate the size of linear documents more easily than hypertext ones. In addition, during a search task it was noted that users found information easier to find in linear rather than non-linear documents (e.g. hypermedia). As a result, there is clearly a need to improve the design and evaluation advice available with respect to navigation in hypermedia and probably 2D environments in general.

In order to gain a further insight into the navigational needs of end users it is relevant to examine their underlying behaviours and any similarity to activities within the built environment. In one study, Bernstein (1998) found that users typically exhibit one or more of nine navigational strategies when using an environment. One example is the montage pattern that points to the existence of districts within the navigational patterns of hypertext users. When individuals navigate in a montage pattern they are seen to move within clearly separable areas of the hypertext document. Bernstein argues that these areas are very similar to the concept of clearly defined localities such as districts, which were uncovered by Lynch (1960) during his studies of the built environment. There is also evidence of clearly defined, salient landmarks within these districts. This is evident from the fact that users typically navigate towards a clearly defined specific point. Canter, who has often written on the subject of real world navigation conducted a study on navigation in complex data structures (Canter, Rivers & Storrs, 1985). Although his findings were at a more abstract level, they did indicate the existence of a set of common navigation strategies by users.

Bernstein also highlighted the circle pattern. This is when the user loops through the same area in two or more times, repeating some the same steps. Several studies indicated that revisitation can account for in excess of 41% (Catledge and Pitkow, 1995; Jones and Cockburn, 1996; Tauscher and Greenberg, 1997) and sometimes as much as 60% (Head, Archer & Yuan, 2000) of all navigation within a hypertext environment. Taking usability from the traditional efficiency standpoint it could be argued that any level of revisitation is a sign of a poorly deigned interface. However, taking a more holistic viewpoint (and as is evident in later studies in this thesis) revisitation is often an activity a user undertakes to gain further information, or to place information in context. As a result, there is often a need to provide some support for revisitation. As well as the problems experienced by users, it is relevant to explore what the underlying cause may be. Conklin (1987) argues that the navigational problems experienced by hypertext users are primarily caused by cognitive overload and/or disorientation.

Navigational problems can also be found within generic user interfaces. An example of this was uncovered by Altman and Larkin (1995) who found that people also experience problems when having to carry out large amounts of scrolling. In addition, Foss (1989) observed that people exhibit three navigational problems when undertaking tasks in 2D graphical user interfaces, namely: *looping and taking inefficient paths; embedded digression;* and the *art museum problem.* In many ways looping is similar to the idea of revisitation, however from the perspective of the design of environments avoiding unnecessary looping is a critical aspect. For example, it should be possible to take a path in any direction or leave it and remain orientated within the whole environment; therefore users should not need to retrace their steps unless they specifically wish to do so. Embedded digression is when the user has a disorganised screen display and has too many windows open at once. As a result he or she may be suffering from high cognitive load demands therefore leading to poor planning, management and execution of digressions. The art museum problem occurs when individuals do not study the information within the environment for a long period of time because of information overload. Instead they gaze at the information and are unable to remember or recall any reasonable amount of it.

Navigational problems can also manifest themselves in the context of poor environmental knowledge. A study by Edwards and Hardman (1989) into the use of hypertext found that in common with navigation in the built environment, it is important for people to be able to possess, as well as make effective use of environmental knowledge and cues. They also argue that where users do not posses adequate environmental knowledge they will suffer from a range of problems, including: *not knowing where to go next; knowing where to go but not how to get there; not knowing the current position.* While these problems were examined in relation to hypertext, in many cases they are relevant to user interfaces in general and to 3D virtual environments. In the built environment a range of cues are typically provided which indicate where they can go next through the use of signs or paths. Similar strategies can also be seen to exist within hypertext documents or generic user interfaces. Knowing where to go, but not how to get there is a common problem with many environments, especially those which are large or complex. In the built environment this can be overcome by providing clear signage, paths, maps or other supporting structures. Within electronic environments, similar concepts can be applied, for example, by using clear and obvious menu structures, which should aid users in being able to correctly locate a desired option. Not knowing the current position in relation to the overall hypertext (or environment) can also be avoided to some extent by providing clear cues as to the current location. A typical strategy is the breadcrumbs technique which lists the user's current location within a website.

3.3 Navigational Models

In order to overcome the problems highlighted and gain a better understanding of user behaviour it is important to consider their underlying navigational models. There have been several studies of user navigational behaviour and a workshop at CHI 97 (Jul and Furnas, 1997) provided an indication that regardless of the type of environment a range of underlying behaviours occur. These behaviours are dependent upon the plans and situated actions of the users and consist of: *locomotion; steering; traversal; route following; route finding;* and *map building*. Locomotion is the act of taking a single step within an environment. Steering is the mechanics (e.g. movement of devices) of moving a single step, and traversal is the sequencing of steps to move in the virtual world. The other behaviours validate the idea of using concepts from the built environment, for example route following examines taking a deliberate path and going from start to finish. Route finding involves uncovering a good path containing the desired properties and paths for the destination. As was discussed in Chapter 2, people can often be seen to be taking paths that are not necessarily the most efficient. Map building is when people start to develop knowledge of the environment.

The Jul and Furnas model briefly explored the idea of plans and situated actions. These two behaviours provide some validation for taking on board concepts from the built environment. For example, when a traveller is navigating using situated actions he or she may rely heavily on cues within the environment as the primary source of information. In the built environment this would be paths, signs or landmarks; in electronic spaces, buttons, scroll bars and menus. In contrast, plan-based navigation assumes some prior knowledge of the space that is utilised by the end user. In many ways the experientialist viewpoint contained within this thesis explores user activities from the situated rather than plan based perspective.

The generic model proposed by the CHI 97 workshop provided an indication of the stages during navigation within electronic spaces. Moreover, by explicitly acknowledging the distinction between plans and situated actions it alludes to the ideas of wayfinding and exploration. Although it should be noted that individuals can undertake a wayfinding task by using explicit cues within the environment, rather than using pre-set plans they may already posses. Putting this issue aside, it is clear that exploration is a critical aspect of navigation. Initial studies by Howes et al. (Howes and Payne, 1990; Howes, 1994) clearly indicate that people do employ exploration as a means of using menus within GUI interfaces and that exploration is a common strategy (Reiman, Franzke & Redmiles, 1995; Rheder, Lewis, Terwilliger, Polson & Reiman, 1995) and one that is beneficial to users (Soto, 1999). It is therefore predictable that several researchers have designed exploration-based interfaces. For example, Bonalndo and Winograd (1997) designed an interface to specifically support the evolution of users' interests in hypertext while they are exploring the space. Others have examined exploration in the context of underlying models (Rheder et al, 1995) or how to evaluate the effectiveness of exploration support within 2D interfaces (Golovichinsky and Belkin, 1998).

Although exploration (or situated actions) is acknowledged, there is no specific part of the CHI97 workshop model that highlights behaviour in an exploration context. This is in contrast with other models, by Head et al. (2000), Spence (1998;1999) and Cove and Walsh (1988), all of whom highlight the benefit of browsing. In the context of these models navigation is seen as a series of tasks that either contain a goal, are goal-less or have some loosely defined goal (see Table 3-1)

The authors of the models in Table 3-1 provide an alternative or expanded viewpoint of the issues from the CHI97 workshop. All the models share one common feature, browsing. Although their exact definition varies between each one, there is a clear indication that viewing interaction in a purely task-based (wayfinding) manner would be incorrect. For example, Cove and Walsh expand upon various types of browsing by indicating that people either have a directed search strategy (known as search/browse).

Head				
Indentify	**Search**	**Browse**	**Organise**	**Re-discover**
Define information retrieval needs	Search for the information	Browse the information retrieved for the most relevant content	Structure environmental knowledge	Revisit certain pieces of information

Spence			
Browsing	**Context Modelling**	**Gradient Perception**	**Strategy Formulation**
Users gather information about the space	Users build up knowledge of the space	Users perceive the difficulty involved in each course of action	Users form strategies based on their knowledge and perceived difficulties

Cove and Walsh		
Search/Browse	**General Purpose**	**Serendipitous Browsing**
A directed search strategy	The user has loosely defined browsing strategy	A completely random browsing strategy

Table 3-1: A summary of navigational models from Head, Spence, and Cove & Walsh.

A strategy that has a strong likelihood of finding something (general purpose browsing), or may have no explicit intention (serendipitous browsing). In contrast, Head assumes that users will have predominantly goal-directed navigational strategies, although they may not posses any knowledge of the environment at the outset. Again, however, this assumption indicates the value of taking into account the need to support situated actions.

The Spence and Head models provide a framework for examining navigation beyond the initial interactions undertaken by users. For example, both models refer explicitly to the ability of the user to create mental images of the environment and structure them into some form of map. There is also a specific indication that users will make use of this map to formulate strategies. In the case of Head's model this may be in the form of revisitation, whereas Spence indicates that this strategy formulation process is dependent upon the perceived gradients (or difficulties) of various navigation options.

With the exception of the Jul and Furnas and the Cove and Walsh models, there is a need to explore the types of environmental knowledge possessed. The previous chapter explored the range and types of cues of that individuals can use in the built environment, in particular the need to explore both physical and emotional aspects. This view is also shared by Shum (1990) in relation to hypertext spaces (see Figure 3-1)

3.4 Environmental Knowledge

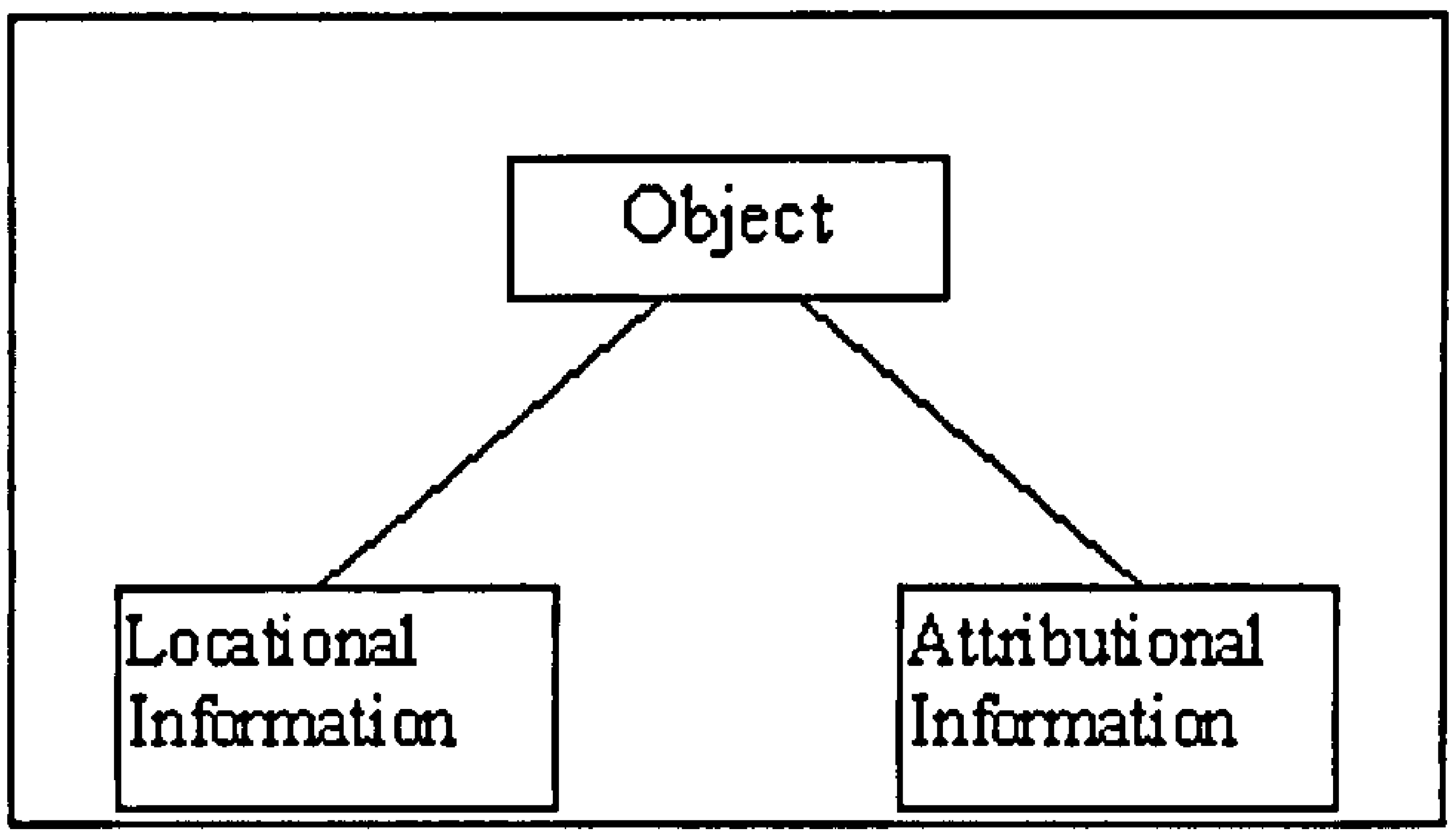


Figure 3-1: The Shum model of a spatial phenomenon, artefact or object.

In a study of hypertext spaces, Shum (1990) found that people typically posses knowledge that consists of two broad categories: locational, and attributional. The Shum model is almost identical to the idea of being somewhere, which was highlighted by Norberg-Schultz (see Chapter 2). Locational information relates to the actual position of an object (or artefact) within the overall space, whereas attributional (or functional) information is properties such as the appearance, sound and the user's personal interpretation. Therefore attributional information will depend upon various properties and relationships, for example *definition, articulation, and space and time.* Definition is the physical appearance of the object, articulation is the feelings it creates, and space and time is the relationship of the artefact to the overall space and time frame in which it was viewed. Therefore, the precise internalised view users have of the artefact will depend on these aspects: the user's context of use and the artefact's perceived reliability (Harper, 1998). The perceived reliability being the user's view as to how accurate and/or non-biased the information contained within the artefact is.

The Schum model of spatial hypertext is at a very high level, however studies of user behaviour within a range of environments have found more concrete evidence of the validity of the navigational paradigm. Several researchers (Ark and Dryer, 1998; Ark, Dryer, Selker and Zhai, 1998) found that adding salient objects, or landmarks to traditional 2D graphical user interfaces helped users in their navigational activities. A more limited study by Heffron Dillon and Mostafa (1996) also found that landmarks did exist and were beneficial within the World Wide Web. This appears to confirm some of the findings by Bernstein (discussed in section 3.2), who found the existence of districts (or montages) and landmarks within the navigational patterns of users within hypertext spaces. There is also evidence to indicate that people describe interaction within a webspace to others in navigational terms, for example using words such as 'forward' and 'back' (Maglio, 1998).

3.5 Applying the Navigational Metaphor

A number of authors have suggested there is a benefit to be gained from considering navigational metaphors as a means of designing user interfaces. For example, Erikson (1993) suggested that current user interfaces are bland, sterile and uninviting. In common with Dieberger and Tromp (1993), he suggests that aspects of the built environment can play an important role in designing electronic information spaces. Dieberger created a MUD/MOO environment for testing whether people would make use of built environment metaphors when communicating and using the environment. The spatial metaphor was further explored by Henderson and Card (1986) who developed a 2D user interface in the style of rooms, however, this met with limited success.

There are a range of other examples where navigational methods have been employed to enhance usability within web and non-web environments. Examples include, a web browser interface was used as a means of accessing standard applications (Lonczewski, 1995) and a mail news/reader to browse the web (Brown, 1995). Dieberger (1996) used a textual environment to navigate the web, a book representation of web pages (Card, Robertson & York, 1996) or navigating web pages using a 3D virtual environment (Smith, 1993). Other methods include: data visualisations such as that of Waterworth (1998) who developed information islands; data mountain (Robertson, Czerwinski, Larson, Robbins, Thiel & Van Dantzich, 1998), which displayed mini versions of WebPages on a mountain; Webtoc (Nation and Plasiant, 1997) which displayed a hierarchical table-of-contents style view; transparent user interfaces (Bier and Stone, 1993); and visual tools such as the magicsphere (Cignoni and Montani, 1994) and fish eye views (Bartram, Ho, Dill & Henigman, 1995). In addition, auditory cues and methods have been explored such as earcons (Brewster, 1998) and other methods (Schmandt, 1998; Morley, Petrie, O'Neil & McNaly, 1999).

In today's information rich navigation experience it is often the case that there are multiple media being presented to the user. This also causes problems for navigation. For example, pictures or sounds are often hard to describe or navigate within and as a result navigational methods that are media-based are now also becoming available (Hirata, Hara & Shibata, 1993; Lewis, Davis, Griffiths, Hall & Wilkins, 1996). All of these methods seek to make navigation easier' but in many cases provide unique usability issues on their own or do not address different types of navigational behaviour or models effectively.

As indicated earlier, there are methods of social navigation that may also help usability. While these are not discussed in any length' it is worth providing a brief overview of some of the more common and interesting ones. One of the more explored aspects of social navigation is the use of scent, residue or clues that a user leaves behind after having viewed information or web pages (Furnas, 1997; Pirolli, 1997; Wexelblat and Maes, 1999). These scents can either be used by other users or the same user when deciding what to view in the future. The basic idea is that just as people will typically follow other people within the built environment and that methods should be provided in electronic spaces that support similar behaviours. Other methods include recipe recommender systems that build up individual and group profiles of peoples's food choices and attempt to advise them on what to buy (Svensson, Laaksolahti, Höök & Wærn, 1999). Another system made use of humour, cartoons and sarcasm to help in web page navigation (Svensson, Persson & Höök, 1999). This system conflicted with many usability concepts as it did not enhance efficiency and introduced redundant information into the navigational experience.

3.6 2D Design and Evaluation Methods

The complexity of electronic information spaces results in the need for appropriate methods to support design and evaluation. As the following section demonstrates, the issue of navigation has not been addressed to any degree within many 2D user interface design/evaluation methodologies. This may in part be because of the heavy bias towards task-based methodologies such as Cognitive Walkthrough and GOMS, however, in addition other methods such as Heuristic Evaluation do not provide sufficient guidance on how to evaluate the navigational effectiveness of an interface.

3.6.1 2D Evaluation Techniques

Cognitive task analysis examines the concepts, the relationships between concepts, and the user's capacity to create relationships (Preece, Rogers, Sharp, Benyon, Holland & Carey, 1994). The partitioning of the information space into concepts allows users to build up a representation of the domain in which space they are interacting and, in turn, to construct models of how to interact within it. The idea of partitioning spaces into a logical order has also been highlighted by Marshall and Shipman (1997), who found that when people were confronted with large amounts of unorganised paper notes they would frequently attempt to partition them into some meaningful and logical order. In contrast, where a sensible order (or grouping) is not devised, users of the information will experience problems. This evident in the New Zealand Ambulance Service where the computer dispatch grouped locations alphabetically rather than by location (Wong, O'Hare & Sallis, 1998).During a study of the system it was observed that when grouping by proximity was used the time taken to dispatch an ambulance fell significantly. This example highlights the effect that unstructured (or inappropriately structured) space with no reference to the user's internal model has on usability.

GOMS is a family of usability methods that break user's task in to various component parts. These consist of the Goal of the user (their task), including any sub goals, Operators, Methods and Selection rules. An operator is the cognitive, perceptual or the physical action required by the user to allow satisfactory completion of the task. Methods are groups of operators or sub-goals and selection rules are conditional constructs. As a result GOMS methodologies focus on plan-based interaction and wayfinding.

One of the main problems with GOMS methods is that there are a large number of variants, each having its own set of benefits and limitations. Initially, GOMS models, in particular keystroke level model (Card, Moran & Newell, 1980a), CMN-GOMS (Card, Moran & Newell, 1980b) and NGOMSL (Kieras, 1997), assume that users have an explicit task, which they are completing in a sequential order and have no other goals or interleaving tasks (John, 1996). In contrast, CPM GOMS (Card, Moran & Newell, 1980b) examines parallel task-based interaction. For the most part these methods assume that the users already have prior knowledge of the environment and how to complete the task. Therefore, the aim is to explore how the user's anticipated method of completing a task varies from the actual implementation.

Cognitive Walkthrough is a predicative usability method based on the theory of learning by exploration (Lewis, Polson, Wharton & Reiman, 1990; Polson, Lewis, Reiman & Wharton, 1992). It can be used on to evaluate drawings, on screen mock-ups and finished systems. It is intended to assess the users' abilities to complete a given task by exploring the interface, and is therefore particularly useful for walk-up and-use systems where the user has not received prior experience or guidance from a third party. The concept of exploration within Cognitive Walkthrough is different to that within this thesis, as exploration in the terms of Cognitive Walkthrough is seen as the user's ability to complete predefined tasks, and not the (semi) goal-less structure of exploration described earlier in this thesis. Although Cognitive Walkthroughs are useful, they are often very time consuming as they require a task to be broken down into its components before any analysis can take place. As a result, Rowley and Rhoades (1992) devised a quicker and easier version known as Cognitive Jog through.

One of the critical problems faced by the methods discussed is that they traditionally ignore aspects related to exploration, whether this is totally or partially goal-less. This is evident in that they assume individuals will already have defined a clear goal and in many cases may already have an externalised a view (or map) as to how they wish to achieve this goal. As would be expected, task-based methods support wayfinding and the learning of environmental knowledge. Although in the case of the latter this is primarily from the perspective of learning route knowledge.

In contrast with Cognitive Walkthrough, Heuristic Evaluation (Nielsen and Morlich, 1990) examines the entire interface, is not task-specific and can be used during design and evaluation. It is a guideline-based discount usability evaluation technique for primarily 2D environments, although the Coven project (COVEN, 1997) has taken some aspects and built on them for 3D virtual environments. Heuristic Evaluation allows a range of evaluators access to a cost-effective and fast method of evaluation by providing them with ten guidelines that they can use to assess the types, frequency and severity of problems within the interface. In doing so it provides a method of detecting serious and non-serious usability problems.

ERMIA (Green and Benyon, 1996) examines the relationship between the conceptual and physical mapping of spaces. While ERMIA is not a usability method in the same sense as GOMS or Heuristic Evaluation, it does allow for designers of almost any object or system to explore this mapping. ERMIA uses a process of mapping the underlying physical representation and then comparing this against the users conceptual model; where there is a mismatch it is assumed usability problems will occur.

3.7 3D Design and Evaluation Techniques

Three dimensional environments such as data visualizations, simulations and games may contain navigational problems for users. Indeed, many of the symptoms and behaviours observed in two-dimensional environments are equally applicable within three-dimensional ones. For example, users may loop, revisit or take inefficient paths. Although navigation remains a problem within 3D virtual environments, there remains one key question in the context of this thesis, i.e. does the concept of navigation in information space and the use of architectural cues apply to the design of 3D spaces? A study by Murray, Bowers, West, Pettifer and Gibson (2000) would suggest that people do think and verbalise in terms of navigational metaphors when interacting in 3D environments. Ruddle, Payne and Jones (1998) also found that a person's ability to navigate in 3D virtual environment improves over time, thereby giving credibility to the idea that spatial knowledge is equally relevant in real and virtual spaces.

Three-dimensional environments range in type and purpose, however, at a general level Bowman, Davies, Hodges and Badre (1999) did provide a taxonomy of usability within such spaces. Bowman et al.'s taxonomy defines eight key aspects of usability of virtual environments, of which spatial aspects do play a part, thee are: *speed; accuracy; spatial orientation; ease of learning; ease of use; info gathering potential; presence; and user comfort.* In addition they define navigation in two ways, firstly the ability to wayfind and the physical act of travel. While this description of navigation is relevant it is quite restrictive in the sense that it ignores many aspects such as exploration or object identification. However, despite the limitations of Bowman et al.'s taxonomy it does indicate that navigation is a key aspect of the usability.

In order to overcome navigational problems within 3D environments several researchers have examined the use of concepts from the built environment in the context of designing 3D virtual worlds. These range from examining individual properties such as landmarks (Vinson, 1999) and maps (Edwards and Hand, 1998) to using American-style city grid layouts and maps simultaneously (Darken, 1995; Darken and Silbert, 1996a; Darken and Silbert, 1996b). Darken defined two key aspects of any 3D virtual environment: imagibility and legibility. Imagability is the ease with which individuals can recall a location and place the physical artefact in the context of their functional uses. Legibility is the ease with which users can organise the space into a coherent order. Darken & Silbert do however suggest that imagible spaces are not necessarily legible. Darken also suggests that imagible spaces will lead to increased user participation.

Others, such as Ingram and Benford (Ingram and Benford, 1996; Ingram, Benford & Bowers, 1996), have also built sample collaborative environments using the Lynch concepts and concluded that nodes, landmarks, paths, districts and edges did improve environmental legibility. In contrast, Charitos (1997;1998) carried out a substantial study into the use of navigational ideas, such as paths, while attempting to do this from an experiential perspective. However, the work of Charitos was very restrictive in the sense that it used abstract environments with no real functional purpose for the user. In contrast, one of the aims of this thesis is to explore the navigational paradigm as a method for designing (and evaluating) interfaces that have some use for users. The work of Charitos typically provided users with very simple tasks that are not likely to be repeated in real-use environments and are primarily from the perspective of wayfinding only. Although Charitos (1997) does provide a set of guidelines, they are not in sufficient detail to fully explore many of the more complex themes of navigation within information spaces. It is worth nothing that the work of Charitos has not been validated on environments built or evaluated by others.

Despite the limitations of the Charitos' work it does indicate the value of the Lynch design concepts. In another study, Charitos found that people will typically follow paths and that using texture maps along path boundaries will enhance movement. He also found that rhythmic boundaries and objects enhance the feeling of movement along a path. Charitos also explored how people behave in relation to spatial boundaries, finding that people will typically prefer to explore boundaries, find exits, locate boundaries and finally face into the space at all times. His study found that people typically feel more secure in an enclosed space; in contrast, openness, detracted from feelings the users had of being secure. Although in his earlier work on taxonomies of 3D navigation Charitos talks about many of the issues examined in this thesis, for example signs, he does not carry out any substantial empirical study of them.

Darken constructed four environments containing various conditions in order to test them for navigability. These conditions were: map only; grid only (the environment was laid out in a US city style); map and grid; and control (no additional features added). It was found that a combination of a grid and map aided navigation to the greatest level. Of the remaining conditions, the next most successful was grid only, followed by map only and control. The map only condition is interesting from the perspective that it appears to place into question the value of using maps as the only aid in navigation. Another example is provided by Bowman et al. (1999) who found that maps decreased navigational efficiency. This can partly be explained by differences in map usage ability by individual users (Thorndyke and Stasz, 1980). From the study Darken concluded that:

- Users will experience disorientation when directional information is not provided.
- Large unstructured worlds are difficult to navigate.
- Users impose a conceptual co-ordinate system on the world.
- People frequently make use of design features e.g. paths, coastlines and grids.
- Maps allow for optimisation of search strategy.
- Dead reckoning will occur. This is when people estimate their location by deducing it from a rough estimate of direction and speed of travel.

Darken also suggested that:

- The world should be divided into smaller units.
- Small parts should be organised with a single organisation principal.
- Frequent directional cues should be provided.

The issues raised by Darken provide evidence that aspects of the built environment are relevant to the design of 3D virtual worlds, in particular the use of directional cues, paths, signs and districts. As an example, this thesis places emphasise upon providing clear directional information either from the environment itself (e.g. paths or other architectural symbols) as well as signs. In addition, by partitioning spaces into clear districts or related areas, this should help the user create some form of conceptual structure. Moreover, this thesis also advocates clearly defining spaces as well as articulating them through the use of emotional cues.

Vinson (1999) examined the effectiveness of adding landmarks within 3D virtual environments and concluded that when appropriately designed and implemented they would aid in navigation. Vinson developed a set of thirteen guidelines which discuss many aspects of landmark design which are relevant to this thesis. Therefore, although this thesis discussed landmarks it will not cover them in as much detail as in many cases the issues have already been discussed and developed by Vinson.

Vinsons's landmark guidelines:

- The environment should contain several landmarks.
- Include five types of landmarks.
- Mark landmarks with destination features.
- Use concrete objects not abstract ones.
- Landmarks should be visible at all navigable scales.
- Use unique objects nearby the landmark.
- The sides of a landmark must differ from one another.
- Landmark distinctiveness can be increased by placing objects near by.
- Landmarks must carry a distinctive feature.
- Place landmarks at major paths or junctions.
- Arrange paths and edges to form a grid.
- Align landmarks edges with path/edges main axis.
- Align each landmarks main axes with those of other landmarks.

Studies into the use of collaborative virtual environments provide some indication of the applicability of spatial aspects to design and how these impact upon user behaviour (Benford and Bullock, 1993; Becker and Mak, 1998; Jeffrey and Mark, 1998). Typical examples include where people appear to adopt personal spaces around themselves within which they would prefer other users not to venture. Designing environments to support chance encounters between users (Benford, Brown, Reynard and Greenlagh, 1996; Huxor, 1998). An example is the ActiveWorlds gateway (the location where people arrive in ActiveWorlds) where, for various reasons people simply remain congregated in the middle of the space. In many cases they do not move away from others unless they are moving to another destination, seeking a private space or are wishing to communicate with different individuals.

3.8 Designing and Evaluating 3D Environments

One method of evaluating virtual environments is the software system VRUSE Kalawsky (1999;undated). VRUSE covers various aspects of VR design including the provision of features to support: functionality; user input (devices); system output (display); guidance and help; consistency; flexibility; simulation fidelity; error correction and handling; immersion/presence; and overall usability. The rationale for the VRUSE system is based around the premises that the end user's perception of usability is critical and that present methodologies ignore several of the challenging aspects of evaluating virtual environments. In order to support this the method invites users to provide feedback on a five point Likert scale. In addition, the users are invited to provide comments in relation to each question therefore allowing a more expressive method of communicating usability problems. The ability of users to provide their own feedback provides a method for them to clarify their thoughts relating to usability problems. Kalawsky suggests that as VRUSE utilises a structured line of questioning and uses a clear rating scale, it provides an informative level of feedback, and is more useful than asking the users to provide written or verbal comments.

The questions within VRUSE are divided into several categories, beyond the initial issues, which they aim to address. Categories include: *disorientation*; *ease-of-use*; *functionality*; *immersion*; *input sensitivity*; *learnability*; *presence; quality*; *simulator sickness*; *situation awareness*; *system performance*; and *system response.* For example, the functionality guidelines relate to various categories including appropriateness, ease-of-use, learnability, and functionality. The linking of the questions to the underlying categories provides a method for evaluators to extrapolate information relating to specific issues e.g. disorientation from the final usability reports produced by the participants.

Support for navigation within VRUSE is limited to two questions asking if the user felt disorientated (one relates directly to disorientation, the other to presence) and it does not provide any questions that ask the users *why* they felt disorientated. However, the problem may be detected to some degree within other questions. The *functionality* questions relate primarily to issues covering the provision of functionality although there is some indication of the importance of being able to interpret and understand the meaning of various features. Nevertheless, this is partially contrasted with the consistency questions, which emphasise the importance of presentation and interaction consistency. Taken to the extreme in this case the highest ratings for an environment would be one which is overly consistent, as a result contradicting some findings that place inconsistency as an important part of the navigation process (Abu-Ghazzeh, 1996).

In common with VRUSE, Kaur (1998) provided a set of generic design principals (guidelines) in paper and hypertext format to aid in the design of virtual environments. A study undertaken using the Kaur guidelines indicated a 66% reduction in usability problems. The guidelines presented by Kaur were based around three interconnected models of interaction within virtual environments: *task action; explore navigate;* and *system initiative.* The *task action* model relates to the behaviour of users when they are engaged in a specific goal or intention (Kaur, Sutcliffe & Maiden, 1998) and the actions that must be undertaken in order to achieve that goal. An example would be when the users approach an object and orientate themselves. The *explore navigate* model is similar to the concept of browsing or exploration. Finally, the *system initiative* model describes user behaviour that is instigated by a feature of the system, either resulting in a user response or the system taking control of the user's behaviour (e.g. teleporting to a specific location).

The Kaur models and guidelines evaluate a number of key areas within virtual environment design. The main issue addressed is basic navigation, for example, within the spatial layout category (e.g. locatable objects, areas of interest, identifiable optimal routes). However, the definition of navigation is wider than that contained within this thesis and includes aspects such as the movement, object avoidance and control of the avatars in the 3D world, thereby moving away from the syntax free style of navigation proposed by Benyon and Hook. As Kaur indicates, the present guidelines do not provide substantial support for navigation.

The Coven project (COVEN, 1997) devised a series of guidelines for design and evaluation of Collaborative Virtual Environments (CVEs) and is based on the single user environment design guidelines devised by Kaur. The guidelines primarily exist in two sections, those for evaluation, which combine aspects of Cognitive Walkthrough with the guidelines style approach of Heuristic Evaluation. The second component provides design guidelines..

The Coven evaluation guidelines extend upon the three basic models of interaction proposed by Kaur: *task action; explore navigate;* and *system initiative* by adding in an additional phase for collaborative interaction. The navigation-specific components of COVEN are confined to two sections. The first, *goal directed exploratory cycles,* examines a series of guidelines for supporting navigation when the user has a specific target in mind, either an object, location or other user. The guidelines provide the evaluator (or designer) with a series of high-level questions, which relate to whether the user can effectively navigate. These include issues such as being able to *know where to start looking, determine a pathway towards the target, be aware of what the next command or action will be.* The exploratory browsing guidelines focus on the stages that will result in effective navigation, for example, *the user determines a path way, user executes movement and navigation activities* and *the user forms a mental map of the explored environment.* As is apparent from the guidelines they assume that the evaluator is able to ascertain what specific design features are required in order to adhere to the individual guidelines. For example, what design feature is likely to aid in people creating mental maps of the environment they have previously explored?

The design guidance offered by Coven examines a range of areas including what is visible to the user, how a user learns, and improving the usability of the system. The issues relating to what is visible to the users provide a high level guideline on making the users aware of their locations in relation to objects and other users. There are also some high level guidelines on spatial organisation and the use of positioning and flow structures (i.e. linkages between rooms or areas). However, in all cases the guidance is at a significantly high level to provide 'catch all' rules, rather than offering specifics on how to implement effective path and route structures, or the issues involved in grouping spaces together. Owing to the high level nature of the Coven guidelines, it is difficult to see what impact they may have on the creation of landmark, route and survey knowledge.

The Coven guidelines represent a significant package of measures to aid in the design and evaluation of virtual environments, but the evaluation method does present some problems. In common with Cognitive Walkthrough it is in effect evaluating a specific individual or group of users for a given task. This when combined with its high level of guidance, means that any evaluation of a virtual environment provides only limited feedback and may not necessarily address in enough level of detail which design features are needed in order to overcome a specific problem. In addition, and in common with Cognitive walkthrough, it is possible that a high number of tasks may need to be carried out in order for the evaluation to be meaningful and there may also be problems with the selection of tasks and the amount of work required (and information produced) by the evaluator in order to gain meaningful results.

3.9 Conclusion

This chapter has discussed navigation from a range of perspectives such as models of behaviour within electronic spaces, the use of the navigational metaphor by users when describing a space and the lack of support for navigation within current usability practice. In essence, the aim is to highlight that the navigational metaphor provides a relevant means of design and evaluation and is important with respect to the behaviour and descriptions that users provide of an environment. Therefore, the navigational metaphor is not only a method of communication between designers, evaluators and users but is also intrinsic in the behaviour people exhibit within electronic spaces. However, despite its crucial importance, as yet it remains largely unexplored within the field of usability practice.

In conclusion, the term 'navigational metaphor' is perhaps not the most relevant to the work contained within this thesis. As a result, and in common with Benyon (1998) the view of this thesis is that navigation is a paradigm or alternative perspective of usability and that interaction within electronic environments is similar to the act of people navigating in the real world, rather than simply a metaphor which can be used to describe interaction. Therefore, there is a need not only to explore the notion of navigation from its many angles but also to provide clear guidance on it to designers and evaluators of information spaces. In contrast with previous works (Charitos, 1997; Charitos, 1998; Ingram and Benford, 1996; Ingram, Benford et al., 1996), the aim is for such guidance that builds on the concepts from Lynch (e.g. nodes, landmarks, paths, districts and edges) and explores how environments can be designed from an experiential perspective. The experiential perspective allows for a focus on not only wayfinding but also exploration or a range of other navigational behaviours, largely from the viewpoint of the user being situated within the environment.

Chapter 4

Developing ENISpace

This chapter discusses a pilot study of some early navigational guidelines. The chapter also discusses the development of ENISpace in its software and paper forms.

4.1 Introduction

As a result of the pilot study described in this chapter and the literature reviews (Chapters 2 and 3) ENISpace was devised. ENISpace (Evaluating Navigation in Information Spaces) is a series of guidelines in software and paper form which examine the navigational cues in a range of user interfaces. ENISpace builds upon The Navigational Instrument (see Appendix A) that contained an early set of guidelines. The Navigational Instrument was devised as part of the PERSONA project by Professor David Benyon and the author of this thesis. ENISpace marked a substantial departure from the Navigational Instrument in two main ways: initially the content of the guidelines and the development of a prototype software version. The new guidelines encapsulate a range of themes from the built environments and draw heavily upon the work of Bacon (1974), Bentley, Alcock, Murrain, McGlynn and Smith (1985), Ching (1996), Lynch (1960), Norberg-Schultz (1971) and on the design of signs (Finke, 1994). The software version included a hypertext style interface with supporting documentation, a reports facility and a range of other features (discussed in Section 4.6).

4.2 Development Process

ENISpace was developed using an iterative process, which included a pilot study, a wide-ranging literature review, software development and feedback from members of the PERSONA project. The underlying concepts contained within ENISpace and the subsequent software versions were subject to feedback at various events such as HCI 98, WebNet 99, UK-VRSIG 2000, The French-British International Workshop on Virtual Reality, and Interact'99.

4.3 The CO-NEXUS Study

During the Spring of 1998 the Navigational Instrument was used to evaluate the CO-NEXUS internet environment. The aim of the evaluation was twofold; initially to evaluate the CO-NEXUS environment and to look at using the Navigational Instrument on a real world system. This was achieved through a mix of expert evaluation and user trials. As a result, the study examined whether evaluators were uncovering problems using the method and whether the basic concepts are relevant to interface evaluation.

4.3.1 Method

4.3.1.1 Subjects and Procedure

The evaluation consisted of three parts; an expert evaluation (stage 1), user observations (stage 2) and a final expert evaluation (stage 3).

- Stage 1 involved the author carrying out an expert evaluation of CO-NEXUS using Cognitive Walkthrough, the Navigational Instrument and Heuristic Evaluation.

- Stage 2 involved observing real users of the CO-NEXUS environment who were then asked questions about their experiences.

- Stage 3 used three expert evaluators who examined CO-NEXUS using the Navigational Instrument.

The reason for carrying out a three stage evaluation was to examine whether the Navigational Instrument uncovered relevant usability issues, to highlight any problems with the Navigational Instrument and whether the issues identified were found using other methods.

4.3.1.2 Equipment

The study used the CO-NEXUS environment (see Figures 4-1 to 4-3) and forms for the Navigational Instrument, Cognitive Walkthrough and Heuristic Evaluation (see Appendix B).

4.3.1.3 Tasks Given to Users and Expert Evaluators

All the expert evaluators and users were given the same tasks to complete (see Table 4-1). The only exception was the chat application, which was only available during the user study (stage 2).

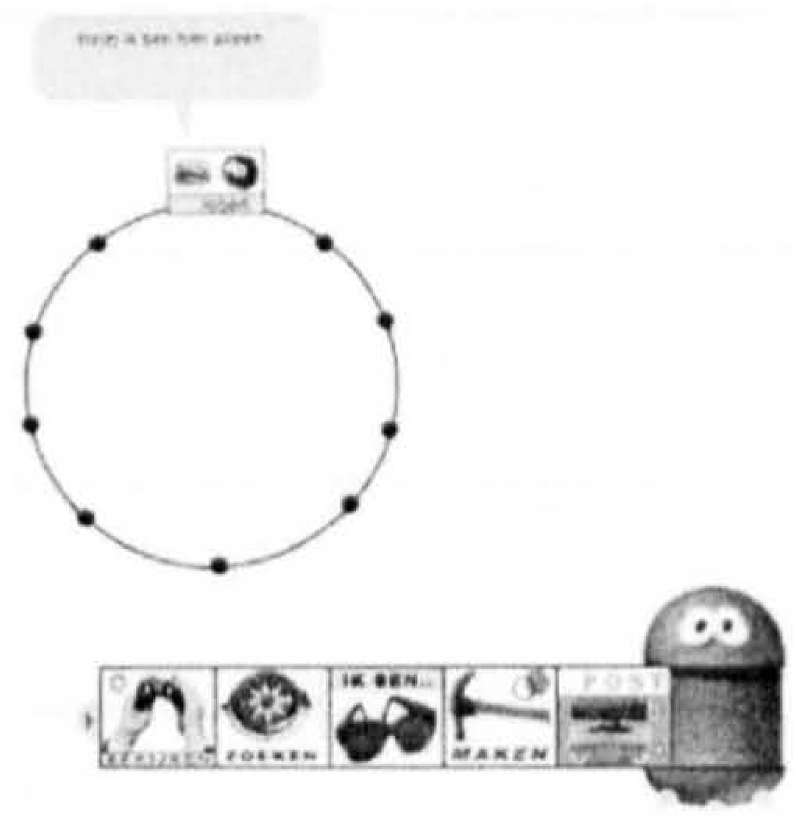


Figure 4-1: The CO-NEXUS chat environment (the circle) with the toolbox (main menu) open. Bert (bottom right) displays the main menu of options when clicked.

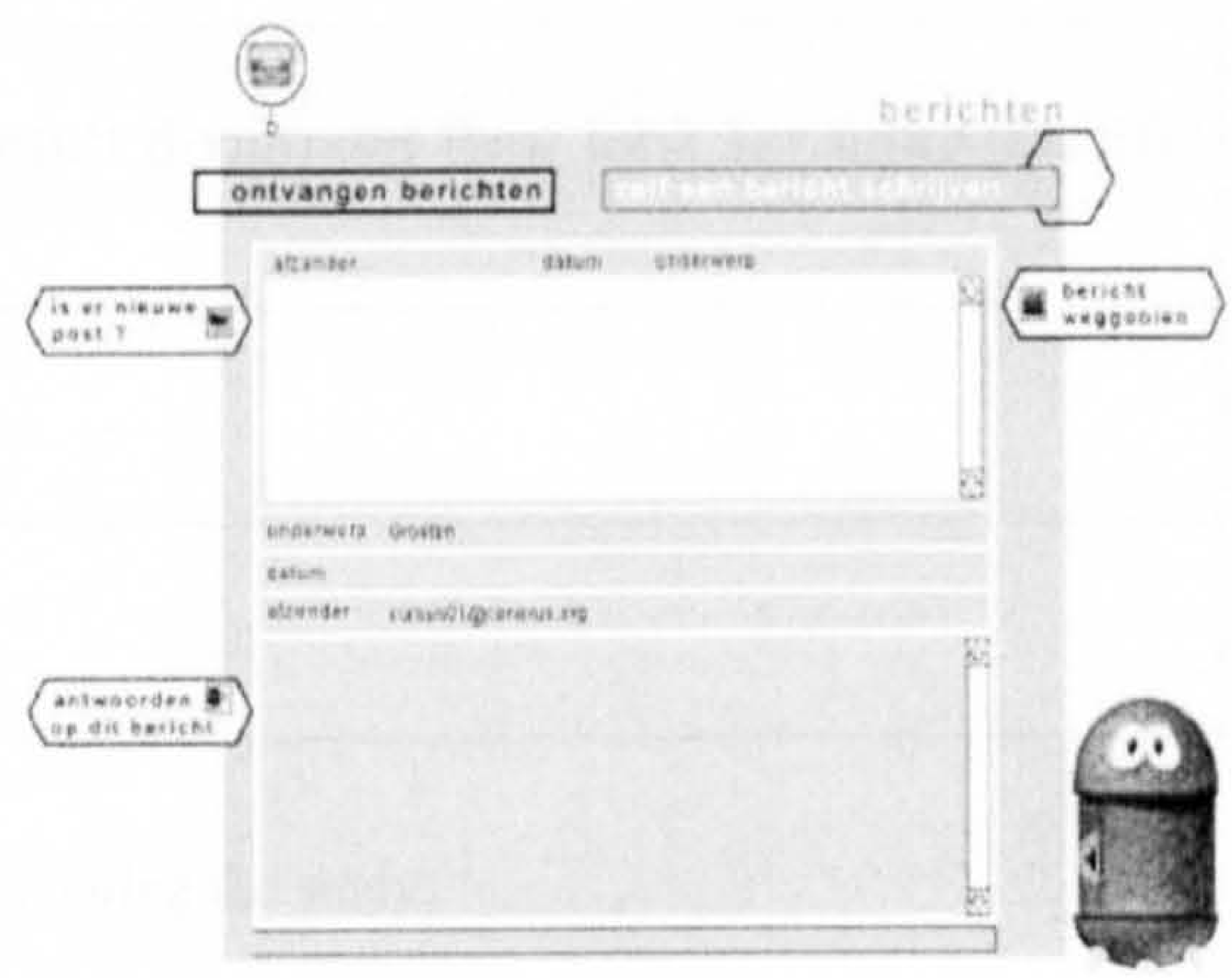


Figure 4-2: The email tool.

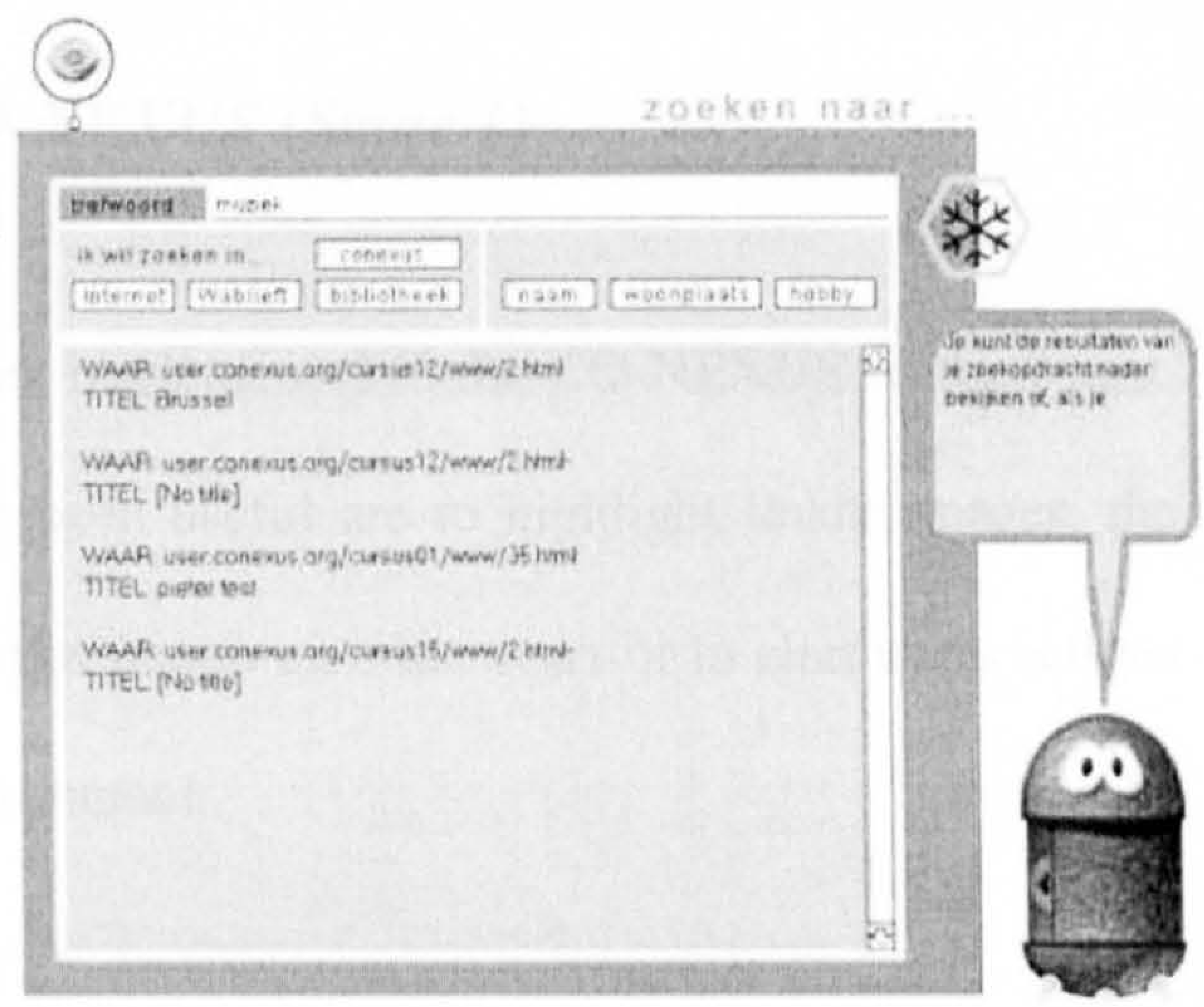


Figure 4-3: The search tool displaying results.

List of Tasks Given to Evaluators and Users	
1	Login to the environment.
2	Use the CO-NEXUS chat room.
3	Fill in the profile form.
4	Search for information on "Turnhout".
5	If they had succeeded in the search task to look for a specific document.
6	Once they had read the search result document then look for more specific
7	Send a short email.
8	Send a message to someone else.

Table 4-1: The tasks given to the evaluators and users during the study.

4.3.2 Results

4.3.2.1 Expert evaluation of CO-NEXUS (Stage 1)

Sound cues are important but were not implemented in the CO-NEXUS environment. Examples of where they would have been useful are to highlight linked spaces, the arrival of new email, a chat request, information on other users or to alert users actions taking place in other areas of the environment.

Throughout the environment metaphors were poorly implemented or not used. Problems included no metaphors being used to display search results and inappropriate icons in the main menu. There were also problems with the use of landmarks, typical examples included large prominent icons which had no function and the main menu being represented as a beehive. Also it was not possible for users to customise the icon used to represent them within the chat space.

The distribution of objects within the space was problematic, the main problem being that there was no clear indication of the user's locations. This problem was made worse by the poor iconography. Moreover, one of the main aims of CO-NEXUS was to allow people to create a new web page, publish the page and email their friends about it, however this task flow was not supported in anyway. This problem was further emphasised by the fact that user had to navigate via the main menu each time they changed from one activity to another.

The navigational aids were poorly designed; problems included lack of links between related areas, no shortcuts, having to navigate via the main menu in order to get to another area of the space and problems with the login interface. The latter forced users to combine mouse moves and keystrokes in a way that was inconsistent with interfaces in other similar applications.

The environment did not make effective use of informational or directional signs. One of the more serious problems involved the use of Flemish language in parts of the interface. This was wholly inappropriate for most of the users as they were unable to speak Flemish. Further problems were found with signs obscuring parts of the interface, a typical example being when a user would open the main menu which would expand across other options within the interface.

In the context of the CO-NEXUS interface, landmarks were primarily the larger more prominent icons. Despite this, many of these icons/landmarks had no purpose. Further problems were found with the Beehive icon that contained the main menu. This icon did not suggest that the main menu was available by clicking on it and the various icons it contained did not clearly reflect their purpose.

4.3.2.2 Results from Other Evaluation Methods (Stage 1)

The Cognitive Walkthrough analysis uncovered a range of issues such as the labeling of the user name and password boxes, no system response when the user clicked on the connect button and use of the mouse to move between the login name and password fields. The latter behaviour is not consistent with functionality in similar systems.

The Heuristic Evaluation analysis uncovered a range of usability problems, including: the consistency of objects and interactions; the memory requirements that were placed on users after a search; poor feedback; and lack of ability to undo an action. For example, having to use the mouse to interact with certain parts of the application when key presses would be more appropriate, pressing the return key in the chat environment automatically initiates a chat and the backspace key behaving differently from other systems. It was also noted that there was poor feedback when sending an email message, and there were problems with the size of text and number of scrollbars on screen.

4.3.2.3 Results from User Study and Observations (Stage 2)

The user study consisted of two main components. First, the subjects were observed by the author of this thesis (or another evaluator) and secondly they were asked questions about their experiences. The evaluators were the class teachers who were provided with a list of issues uncovered during the expert evaluation; they were also asked to note down any other problems that were observed.

Users experienced a range of problems with the login screen including lack of feedback and the delay between pressing the login button and actually being logged in. As a result, users would often click on the login button several times. Problems were also identified when entering the user name and passwords as this required using keys to enter the details and use of the mouse to move between the different fields.

The chat option contained some problems for the users. Initially many users were unable to find the chat feature within the menu (perhaps owing to poor iconography). In addition once they had located the chat feature they did not realise that they needed to press the enter key to send a message.

The email tool caused severe problems for many users, mainly due to the use of the Flemish language which frequently resulted in users deleting messages as opposed to sending them.

4.3.2.4 Results from the Expert Evaluation (Stage 3)

The final stage entailed three evaluators using the Navigational Instrument. The evaluators were two PhD HCI students (who had no prior experience of the Navigational Instrument or CO-NEXUS) and Professor David Benyon. A summary of the responses is provided in Table 4-2. The results from the final expert evaluation uncovered a range of issues including prominent icons having no function, poor grouping of related items and confusing navigation buttons. Further problems included the main menu icon (a Beehive) not being immediately obvious, and the availability of menu options changing for no apparent reason. Additional areas of concern were noted in that no shortcuts, paths between related areas, guided tours and predefined routes (e.g. wizards) were provided.

"Why is the snow flake used on several screens but has no purpose?"
"Related icons are grouped together… but related tasks are not."
"Unsure why menu size changes"
"Menu options change"
"No maps, no guided tours"
"Not clear when search results returned"
"Pre-formatted routes between objects not clear"
"No indexing/landmarking facilities"
"No shortcuts"
"Some objects are important but do nothing"
"Difficult to recognise menu at first"

Table 4-2 Comments from the expert evaluators.

4.3.2.5 Using the Navigational Instrument

The results from this part of the study indicated that findings between evaluators were often inconsistent, this indicates that background information on the navigational concepts should be provided so that evaluators can gain a better understanding of what they are evaluating. The provision of such information will hopefully lead to a higher degree of consistency between evaluators.

Comments made by the evaluators indicated that there were problems with the design of the Navigational Instrument, one of the most common being that related guidelines in different sections were not linked. Moreover, the rating scale used to highlight problems provided a very course level of analysis with three measures used good, used poor or not applicable. This often resulted in a substantial spread of results as the evaluators were unable to assign an appropriate score to usability problem. In addition there was no way to extract any data from the results provided by the evaluator, therefore it was difficult to gain a meaningful overview of the results.

4.4 Moving Forward

The results of the pilot study indicated the relevancy of considering navigational concepts when evaluating user interfaces. However, as was acknowledged earlier, the Navigational Instrument did not include many of concepts uncovered during the literature reviews in Chapters 2 and 3. Moreover, the CO-NEXUS study pointed to problems with the Navigational Instrument such as: lack of supporting documentation; no links between related guidelines; and no easy way of extracting results from an evaluation.

As a result of the user study and the work contained within Chapters 2 and 3, ENISpace was developed. ENISpace encompasses more of the ideas contained within the literature reviews, resolves some of the problems with the Navigational Instrument and exists in software and paper form.

4.5 The Components of ENISpace

ENISpace is split into four main sections namely *Conceptual and Physical Structure;* and *Signs within the Environment,* which are developed within this thesis, and two sections *Navigational Methods and Aids and User Within the Space* which are not. The Conceptual and Physical Structure section consists of 35 guidelines in three main subsections: examining *space syntax and semantics*, *landmarks*, and *paths*. Note that the definition of *space syntax* in this thesis varies from that of Bill Hillier and the researchers at The Bartlett School of Architecture, University College London in that it does not examine pedestrian flow and social implications in the same way. The *signs within the environment* section encompasses all aspects of adding signs such as color, layout, positioning and links to other cues within the environment.

One of the principal objectives of ENISpace is to build upon aspects that deliberately support various types of environmental knowledge and behaviour. A typical example being the inclusion of guidance for the design of routes and paths, which typically help people when wayfinding or exploring. Other changes include embracing the Lynch ideas of identity, structure, congruence and significance (see Table 4-3), and the concepts of variety, robustness and permeability (Bentley et al., 1985). The sign design guidelines were developed more fully to include many of the aspects such as design and placement. All these issues are discussed in Chapter 2.

IDENTITY	The ability to recognise and recall an environment.
STRUCTURE	Allow the user to understand the implied context and use of environment.
CONGRUENCE	Mapping from functional to physical form.
TRANSPARENCY	Ability to be aware of functions without information over-load.
SIGNIFICANCE	The ability to gain a knowledge of the space.
UNFOLDINGNESS	The ability to gain a gradual knowledge of the space through use rather than explicit instruction.

Table 4-3: The Lynch Concepts.

4.5.1 Conceptual and Physical Structure

These guidelines examine the relationship between the physical aspects of the space and the conceptual properties it contains for end users. It contains three main sections: *space syntax and semantics*, *landmarks,* and *paths*. The objective of this section is to examine how the various attributes such as the layout (syntax and semantics), landmarks, and paths will affect the user's mental model of the space. The user's mental model of a space is derived from a range of aspects, including: intended activities; navigational behaviour; the functionality of the space; previous meaning attached to the objects or areas; and the users subjective feelings towards various features. Although there are similarities with the work of Lynch (in relation to landmarks and paths), the guidelines have moved away from recommending aspects such as districts, nodes and edges to examining which aspects will result in the creation of such environmental features. For example the guidelines provide information on relationships between spaces.

4.5.1.1 Space Syntax and Semantics

Space Syntax and Semantics covers a range of components including *User Experience, Definition and Articulation,* and *Opportunities and Activities.* The primary motivation for this section is to examine how user experience, meaning (definition and articulation), and opportunities and activities will affect behaviour and the ability to navigate.

This section of ENISpace draws heavily on the work on spatial layouts by Bentley et al. (1985), Ching (1996) and Lynch (1960). However, it should be noted that while the concepts explored by Ching are relevant, they are not provided in the form of specific guidelines. The section also explores aspects of meaning and behaviour examined in the books by Broadbent (Broadbent, Bunt & Llorens, 1980a; Broadbent, Bunt & Jencks, 1980b), studies of meaning in urban images by Harrison and Howards (1980), the writings on existential space by Norberg-Schultz (1971), environmental interaction by Rapoport (1982) and finally the view of artefacts within electronic spaces advocated by Shum (1990).

The *User Experience* subsection (Table 4-4) focuses on aspects such as reducing memory load. For example, if the environment forces the user to remember too many pieces of information there is an increased chance of the user becoming lost. In order to effect reduction in memory load it is more desirable to balance presentation of information early on, with having it gradually unfold as the user navigates. The section also focuses upon past user experience also the ability to customise (and update) the environment.

Minimise Memory Load	Keep the memory requirements for each task or activity as low as possible.
Emergent Opportunities	Allow features, functions and activities to emerge through using the system rather than via explicit instruction.
Minimise Cost of Update	Allow the user to update/customise the environment quickly and easily.
Relate to User Experiences	Make sure that features and options are designed in such a way as to map on to any prior experiences users may have had.

Table 4-4: The above guidelines are from the Conceptual and Physical Structure, User Requirements section. They focus on issues related to user needs and behaviour.

The Definition and Articulation guidelines (Table 4-5) explore the physical, meaningful and emotional attributes of spaces. The purpose of these guidelines is to draw attention to the link between mapping the physical attributes and the user's conceptual view.

The *Opportunities and activities* guidelines (Table 4-6) within ENISpace examine issues such as variety, robustness and the need for private areas within a collaborative space. The guidelines explore how in real and electronic spaces there is often support for range of activities; for example, in Microsoft Word users can write scripts, letters or academic papers each requiring different fonts, styles and functions all supported by the same interface structure. As a result it is important that designers allow users to undertake a range of activities or several ways to complete the same activity.

Define Important Spaces	If a space has some important purpose then use colours, forms and other means to make sure that
Define Spaces with Different Functions or Requirements	Ensure that spaces with different functions/ requirements are clearly indicated.
Define Spaces with Related Functions.	Where spaces are related provide a means to make this clear.
Articulate Spaces Which Have an Emotional Intent	For example if a space is meant to be fun then some cues should be provided which indicate this.
Appropriate Mapping from Physical to Conceptual Structure.	Ensure that the method of interacting with a space or viewing its content maps onto the conceptual view of end users.

Table 4-5: The above guidelines are from the Conceptual and Physical Structure, Definition and Articulation section. They examine how different spaces are designed and related to one another.

Variety	The space should house many activities.
Private spaces	Provision of spaces which are away from other users.
Robustness	The space should allow for a change of use or activities.
Clearly Indicate Size of Space	The size of the space should be clearly indicated.
Mutual Exclusion	Spaces which are not socially or functionally compatible should not be placed together.

Table 4-6: The above guidelines are from the Conceptual and Physical, Opportunities and Activities guidelines.

4.5.1.2 Landmarks

Landmarks provide a method of orientation for many users in real (Devlin, 1976; Lynch, 1960; Coucelis, Golledge, Gale & Tobler, 1987) and in 2D/3D electronic environments (Ark and Dryer, 1998; Heffron, Dillon & Mostafa, 1996). As a result, landmarks play an important part in the mental maps created by individuals and according to Siegel and White (1975), are the first stage of environmental knowledge. The ability of a landmark to support users is dependent upon its visibility, positioning, the type of users for whom it is intended, and their subsequent navigational behavior. There should be an appropriate number of landmarks for the activities being undertaken by users and they should be relevant to the functionality of the environment (see Tables 4-7 and 4-9).

Clearly Visible	
Clarity of Function and Content	If the landmark has any function or content this should be made clear.
Clearly Separate from Other Objects	
Emphasise Key Landmarks	

Table 4-7: The above guidelines relate to the Conceptual and Physical, Landmarks, Information provided guidelines and explore visibility and types of information a landmark provides.

Allow Orientation	Landmarks should be placed at points that permit orientation within the environment.
Appropriate Number	There should be an appropriate number of landmarks in relation to the size and structure of the space.
Functionally Relevant	
Relevant to Users	The designs of landmarks should be relevant for the users (i.e. gender, age, experience).
Landmarks and Route Awareness	Landmarks should be used within routes to enhance the feeling of travelling the route and to provide nodes or other cues.
Gestalt	Landmarks should make use of some of Gestalt psychology design principals.

Table 4-8: The above guidelines relate to the orientation , function and relevancy of landmarks for users within the space.

4.5.1.3 Paths

Paths provide a method of movement and help in the development of environmental knowledge. The paths guidelines draw heavily upon the work of Downs and Stea (1977) and Ching (1996); in particular in providing path cues that clearly indicates the stage a person is within a path (Table 4-9). Other physical aspects that are examined include the differentiation in paths, and supporting the activities of users (Buttimer, 1980; Kishnani, 1999; Venemans, 1999). The guidelines also explore the experientialist aspects of paths advocated by Bacon (1974) and Norberg-Schultz (1971).

ENISpace recognises that paths can heighten awareness of individual features and reduce travel times to destinations. As a result it is important to consider how the path structures integrate with other environmental features (Table 4-10). Typical issues include allowing quick methods of access to related areas, integration with other features and signs as well as promoting awareness of different areas of the environment. Paths can be integrated with focal points to allow users to view an environment from an optimal point, thereby reducing their need to continually move in order to view

Clearly Marked Paths	Paths should be obvious from other features.
Differentiation in Paths	Paths with different purposes should be clearly
Clear Within Path Markings.	Cues should be used to indicate to the user they are

Table 4-9: The markings of paths guidelines.

information.

4.5.2 Signs

The signs guidelines draw primarily upon the work of Finke (1994) and Abu-Ghazzeh (1996;1997) both of whom studied the sign systems in various cities. In addition they explore the effect signs have on attracting users' attention and making them use facilities (Bittner, 1992). Finally, the directional signs guidelines are also based upon the principals of wayfinding within the built environment as advocated by Downs and Stea (1977) and Passini (1984; 1999).

Activity Based	Paths should reflect the likely activities of users
Short Distances in Related Areas	Paths should allow quick movement to related
Clear Initial Encounter	The start of a path should be clearly indicated.
Clear Approach	As the user approaches a destination or end of
Clear Arrival	Arriving at the end or destination of a path
Integration with Signs	Paths should integrate with the information, directional and warning signs used.
Integration with Environment	They should take sensible routes, unless it is specifically required (e.g. in simulations).
Path Focal Points	The path structure should allow for focal points within the environment to be articulated.
Awareness	The paths should promote awareness of the environment it is within.

Table 4-10: The support for activities and navigational information provided by paths.

Visibility of Signs	Signs should be visible.
Visibility of Environment	Signs should be placed in the context of the overall environment and not obscure aspects of the space.
Consistency	The design of signs in a particular group should be consistent.
Inconsistency	Inconsistency in the design signs between different types should be used.
Definition of Space	Signs should help define the space they serve.
Articulation of Space	Any emotional aspects of a space should be reflected in the design of the signs.
Use of Color Metaphors	
Use of Symbolic Metaphors	
Use of Language Metaphors	
Use of Auditory Metaphors	

Table 4-11: The Global Design Issues which reflect in all sign types. The metaphors guidelines apply to each of the sign types.

4.5.2.2 Directional Signs

Directional signs provide an important method of helping people navigate and in the creation of route and survey knowledge. This section contains four areas: *markings, information and mapping, route markings and general issues* (see Tables 4-12 to 4-14).

Directional signs provide a range of wayfinding support cues (see Table 4-12) including the *distance or time* to reach a destination, *direction* and marking for specific routes. The *markings* section builds on the issues found within the *route markings* guidelines while at the same time recognising that there are certain global issues e.g. the ability to identify different routes. In essence, the *markings* section provides generic global information for the support of all route structures within the environment.

Clear Marking of Distance/Time to Reach Destination.	
Clear Marking of Direction	
Alternative Routes	Any other available routes should be clearly
Mark Optimal Routes	If there are several routes to the same destination

Table 4-12: The markings guidelines within the directional signs section.

The *information and mapping* section (see Table 4-13) examines the relationship between the user, the underlying environment and the provision of directional signs. The guidelines cover reducing the risk of information overload by providing too many signs, enhancing the user's ability to obtain a clear and accurate mental map of the environment, the provision of dynamic (or updating) information and the use of minimalist design.

Within any environment there are a range of tasks undertaken by users, or tasks that the designer would like users undertake. The *route markings section* (see Table 4-14) examines the relationship between supporting user tasks and the development of environmental knowledge. The guidelines do this by alerting the designer/evaluator of the need to provide a clear hierarchical structure consisting of *initial encounter, approach* and *arrival* (Finke, 1994). These issues correspond to recognising the existence of a route (initial encounter), becoming aware of approaching the destination (approach) and being aware of arrival (at the destination). ENISpace also indicates that the user should be able to move between different routes through the *clear transition* guideline.

Appropriate Level of Signage	There should not be too many signs
Clear Location Information	The signs should contain clear information on the location they are pointing to.
Clear Mapping	Information contained within the signs should map clearly onto the desired features within the environment.
Minimalist	The sign should not contain too much information.
Dynamic Information	The sign should provide information on new options or information.

Table 4-13: The markings guidelines within the directional signs section.

Finally, the *general issues* section (see Table 4-15) considers issues beyond directional signs, such as the ability to remain orientated within the whole environment, leave named route structures, and whether the signs are appropriate for users from the perspective of their individual differences and intended activities.

Clear Marking of Route	Each route should be clearly marked.
Clear Inititial Encounter	The first encounter of the route should be clear.
Clear Approach	Approaching the destination should be clear.
Clear Arrival	Arrival at the destination should be clear.
Clear Transition	Moving between different routes should be easy.

Table 4-14: The route markings guidelines within the directional signs section.

Easy Orientation Within Whole Environment	The route should allow for orientation within the whole space and not just that particular route.
Appropriate for Users	All routes should relate to the desired tasks or activities of the users.
Easy Exit	It should be possible to easily leave a route and remain orientated within the whole space.

Table 4-15: The above guidelines reflect how the routes should support users knowledge of the whole environment and be appropriate for their tasks.

4.5.2.2 Informational Signs

The informational signs section (Table 4-16) consists of five guidelines that reflect issues such as correctly identifying other users, objects and locations. The guidelines point to the importance of considering the relationships between information, warning/ reassurance and directional signs.

Other User Information	Provide information on other users within the space.
New Options or Information	Display information on new options or information which may become available.
Uniquely Mark Objects	
Uniquely Mark Locations	
Sign Integration	Informational signs should complement the content of other signs within the space.

Table 4-16: The informational signs guidelines.

4.5.2.3 Warning and Reassurance Signs

Warning and reassurance signs (Table 4-17) help prevent users from taking decisions that may cause problems or to reassure them that they taking the right course of action. In common with other signs types warning/reassurance signs should be clear and an appropriate number should be provided, if too many are provided there is a risk of people ignoring them.

Clear Warning Signs	Warning signs should be clearly separable from other signs types.
Appropriate Use	Warning signs should only be used when necessary and there should not be an excessive number.
Non-Replacement	Warning signs should not replace the features which prevent the action from taking place.
Positive Feedback	Positive feedback should be given where necessary.

Table 4-17: The warning and reassurance signs guidelines.

4.6 ENISpace Software

During the development of ENISpace it became apparent that the number of guidelines, the need for supporting documentation and reporting features meant that a paper-based system was not always appropriate. As a result, a software version of ENISpace was developed which added in features such as a basic reports generator, links between related guidelines, an improved method of rating usability problems and a variety of supporting documentation options.

4.6.1 Overview of the User Interface and Features

The software utilises a browser metaphor for the main menu, data entry screens, supporting documentation and reports generator. The browser style features including back and forward buttons, bookmarks (see Figure 4-4), history list and a visualisation of the path taken through the environment by the user (not implemented). The bookmarks options (not fully implemented) are designed to allow the adding of bookmarks to any area of the interface; for example the supporting documentation of the guidelines. The bookmarks system enhances the look and feel by allowing users to assign icons to each bookmark.

The interface contains a number of design features that are based around the guidelines. First, consistency and inconsistency are used at various points, for example coloured backgrounds are used to differentiate different groups of options. Moreover, the conceptual and physical structure of the guidelines is illustrated through an overview map, which indicates the different groups and some of the relationships between different guidelines.

The interface makes use of more concepts from ENISpace, for example a range of alternative routes are provided within the main data-entry screen. Evaluators can visit any subsection in the guidelines by clicking on a link either in the map on the left or by going via the main icons (Figure 4-5). In addition, dynamic information is provided that indicates when comments have been added or when the evaluator has already visited a section. Short distances are used within related areas; for example, it takes only one click of the mouse to go from one set of guidelines within the signs section to another. The environment does not contain any long routes or paths to get to a final destination and arrival at any destination is usually only one or two mouse clicks away. However, where routes are provided (e.g. the links within the information point) they do make use of certain ENISpace guidelines. For example, their appearance and style (they contain the name of the destination). Moreover, on arrival at the intended destination the screen display changes and the name of the current (sub-)section being viewed is clearly visible at the top of the data entry form. The current location is also displayed within the information point (map).

4.6.2 Data Entry Screens

On starting ENISpace evaluators can enter details of a new evaluation or retrieve them from a previously saved file. After entering or retrieving the evaluation information and clicking continue they are then presented with the main menu. This menu allows them to navigate directly to any sections of the ENISpace guidelines they wish, however in this version only *Conceptual and Physical Structure* and *Signs* are implemented.

The data-entry screen (Figure 4-5) provides access to the majority of tools within ENISpace. The data entry screen consists of the navigation tools and signs (or labels) indicating the current set of guidelines. The screen also contains additional navigational cues such as an information point (overview map) that displays a list of all the relevant sections for that topic, e.g. all the sections within the signs topic. The evaluator can indicate whether a guideline is relevant, the frequency and severity of any errors and finally any comments they may have.

4.6.3 Reports

The software provides two basic report types, both provide a link between the data entered and the underlying navigational models and frameworks used within ENISpace. The report generator produces a series of HTML pages with links to relevant supporting documentation. The reports can be viewed or saved for later use.

The first report (Figure 4-6) provides an overview of usability problems in relation to specific groups (or sections) of guidelines. Any problems are highlighted in relation to the frequency and severity of errors for each guideline and each group of guidelines.

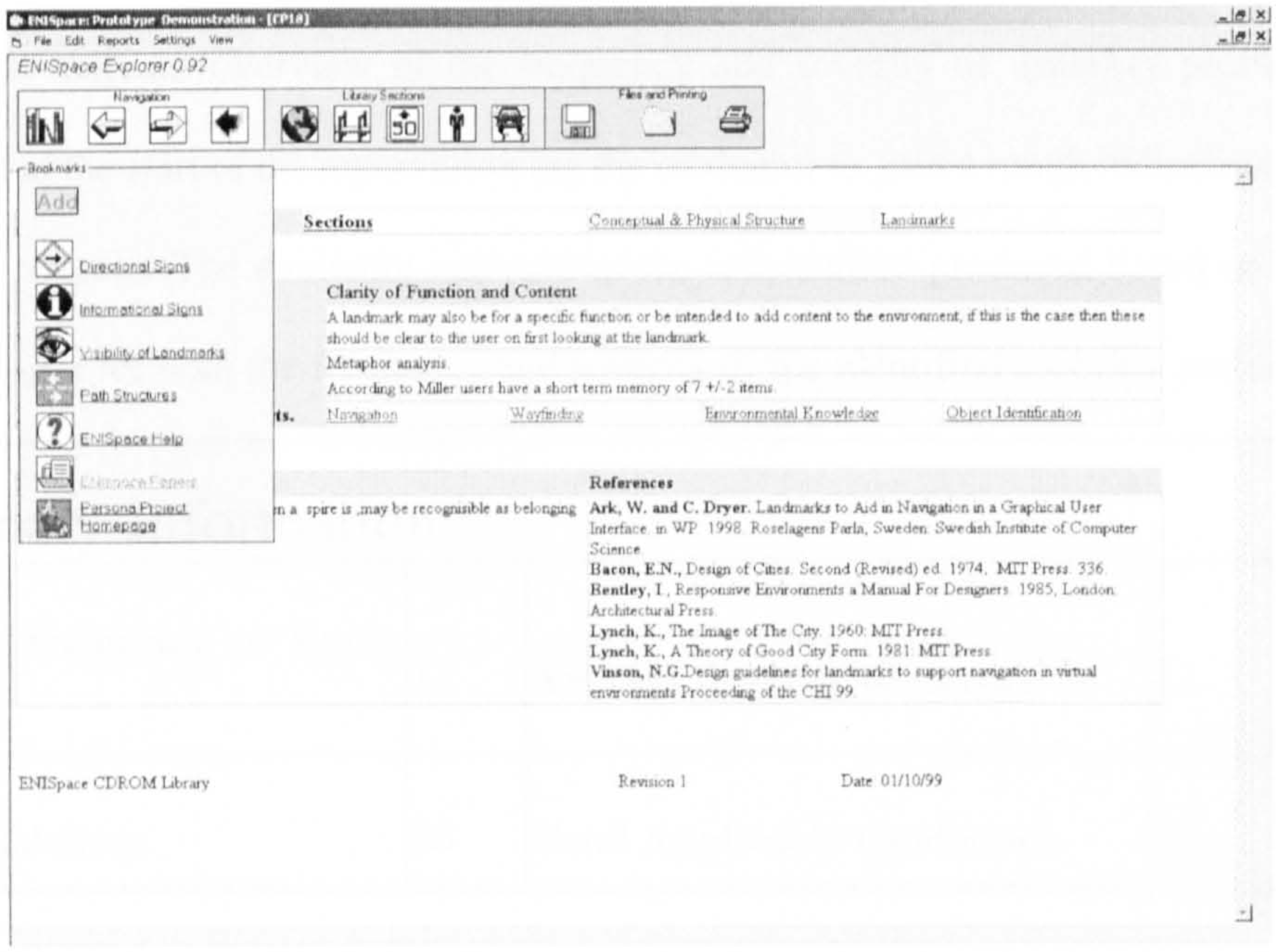


Figure 4-4: The supporting documentation browser widow. It consists of (from left to right) the bookmarks list, the top toolbar and in the centre the main content.

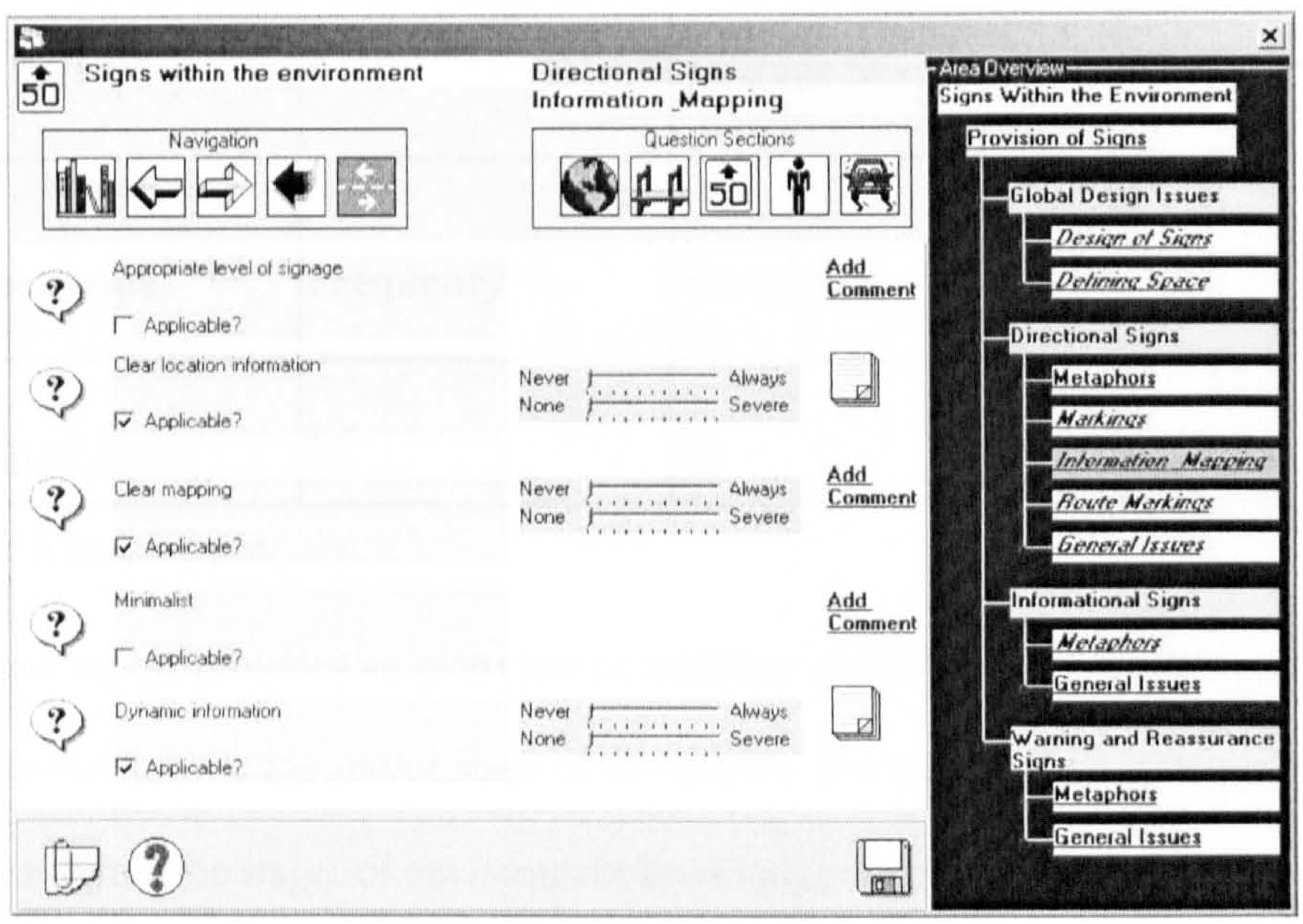


Figure 4-5: The main data entry screen. The central area contains the guidelines, rating scales and comments. The overview on the left contains the list of all the sub-sections in the current section.

Further to this, an overview of the frequency and severity of usability problems is provided at the start of the report allowing the evaluator to gain a rough indication of any areas of concern. The evaluator can restrict the information produced based on ranges and averages for both the frequency and severity of the identified usability problems.

Summary Information			
Average Frequency of Errors %	11	**Average Severity of Errors %**	11
Total Guidelines	80	**Total Applicable Guidelines**	29

Signs:Global Issues: Defining Space			
Total Frequency of errors	2 (10)	**Average Frequency %**	20
Total Severity of	4 (10)	**Average Severity %**	40
Guideline Name	**Frequency %**	**Severity %**	
Definition of Space	20	40	

Figure 4-6: A sample report.

The second report provides an overview of usability problems from the perspective of environmental knowledge and/or stage of navigation. The report that is produced can be broken down into the stages of environment knowledge (e.g. landmark, route and survey knowledge) and/or based around a navigational model (e.g. The Spence Framework).

4.6.4 Library

ENISpace provides supporting documentation, which can be accessed from data entry screens and the reports (when viewed in a browser). The documentation can be retrieved from the local machine or a remote server, the latter allows the evaluators access to the latest version of the supporting documentation. The supporting documentation consists of a page for each guideline containing the information outlined below:

Location: The location of the guideline within the overall structure of the guidelines.

Guideline (Name): The name used within the ENISpace software.

Description: A definition of the guideline and where applicable a description of its context of use.

Analysis: Any advice on how to analyse environments in relation to the specified guideline.

Comments: Additional information which may be of use.

Impact: Which aspects of navigation and the construction of environmental knowledge it effects.

Examples: From real or electronic environments.

References: A list of useful references for the evaluators.

The library consists of a series of web pages, which make use of some aspects of the ENISpace guidelines. An example is the use of colour as a means to emphasise or de-emphasise certain aspects and to provide a method of grouping objects on screen.

4.7 A Sample Scenario

Using ENISpace is a comparatively simple task and a sample scenario is provided in Figure 4-7; the numbers in brackets denote the picture or stage in the sample scenario. First, the evaluator enters the details of the new evaluation (1) then selects the set of guidelines they wish to explore (2). They then indicate which guidelines are relevant and enter the scores for the frequency and severity of errors (3). During this stage they can enter some comments (4) or view the supporting documentation contained in the library (3b). They can then create and view a general navigation report (5) or a specific guidelines report (6).

4.8 Conclusions

This chapter has discussed the development of ENISpace from the Navigational Instrument through an early pilot study and finally ENISpace itself. The chapter has shown that considering navigational concepts is a relevant method of evaluating user interfaces and that a range of valid usability issues can be uncovered when using such a method.

The main part of this chapter covers the development of ENISpace, which provides a 'lens' through which to view navigational issues. The software and paper versions of ENISpace contain a substantially wider range of guidelines that are drawn from the literature reviews in Chapters 2 and 3 and the issues uncovered through the use of the Navigational Instrument. Moreover, the software version overcomes many of the problems associated with lists of guidelines and contains extra features such as easily accessible supporting documentation and a report generator.

A Sample Scenario Storyboard

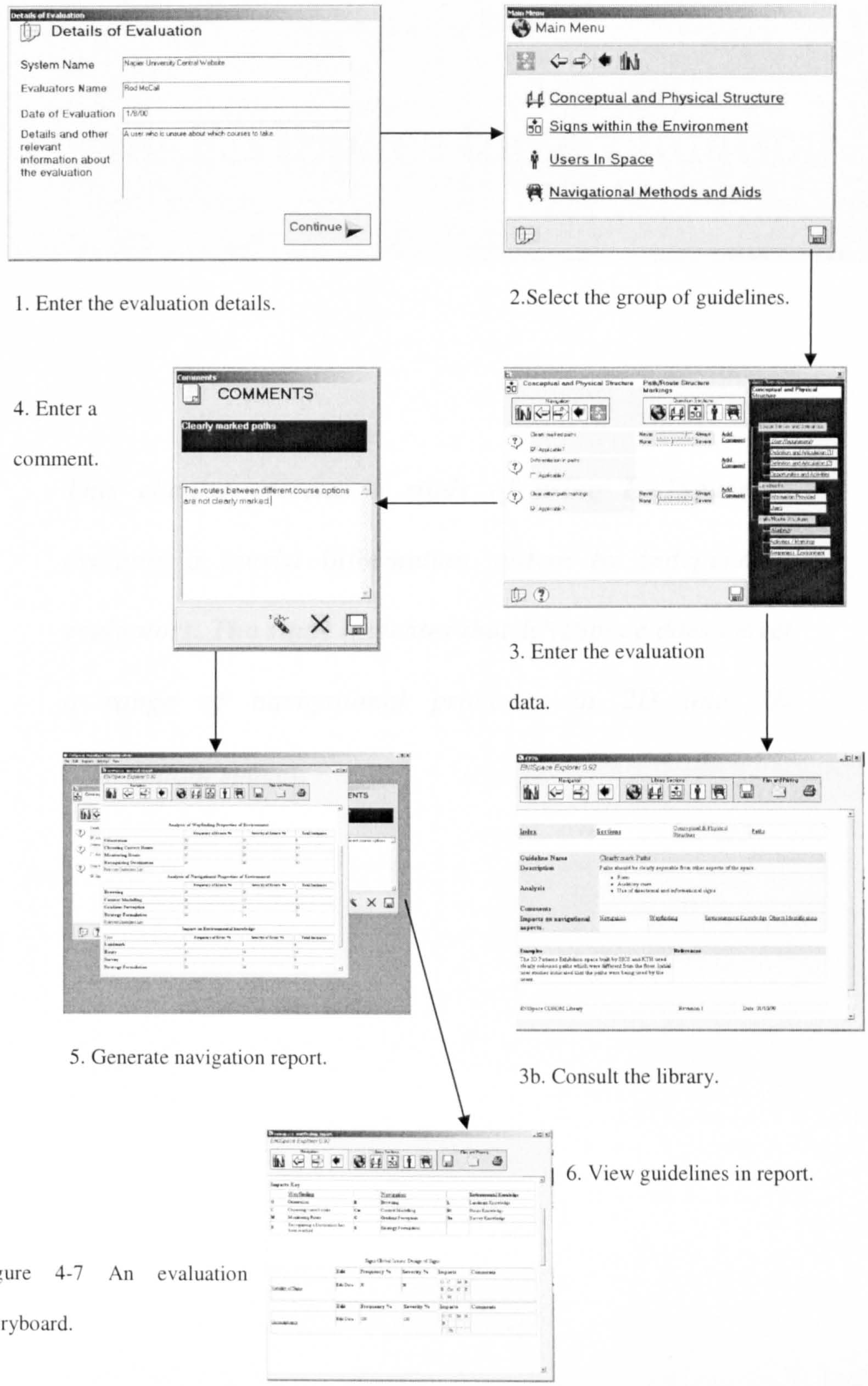


Figure 4-7 An evaluation storyboard.

Chapter 5

Using ENISpace for Evaluation

This chapter presents a study of using ENISpace to evaluate a tourist information system by independent evaluators. The study indicates that ENISpace does detect a range of navigational problems in 2D and 3D information spaces.

5.1 Introduction

From the literature reviews in Chapters 2 and 3 and the subsequent development of the guidelines in Chapter 4, there is a need to explore the relevancy of the concepts contained within ENISpace. This chapter documents a study of using the ENISpace software system (which includes the guidelines) as a means of evaluating a tourist information system. The study examines the wider concepts contained within ENISpace (see section 5-2) rather than the specific guidelines or the software.

The following chapter presents an empirical study that examines the research questions contained within this thesis:

(1) Is there a transfer of design knowledge between real and electronic spaces?

(2) Can the concepts be provided in a series of useful guidelines?

(3) Are the guidelines useful for evaluation and design of electronic spaces?

The chapter contains an overview of the key concepts of ENISpace, the study method, the results found, issues with the guidelines themselves and the software system, a discussion, and conclusions.

5.2 The Key ENISpace Concepts

In order to explore the research questions contained within this thesis, there follows an examination of ENISpace from the range of underlying concepts (see Table 5-1) rather than the specific guidelines. These areas correspond to the main sections within the software, with the exception that the space syntax and semantics section has been broken down into more categories.

	The Main Concepts within ENISpace
C1	Directional Signs should be provided. The signs should provide detailed information on general direction as well as specific routes.
C2	Informational signs should be provided.
C3	Warning and reassurance signs should be provided.
C4	The environment should be matched to the requirements and prior experiences of individual users.
C5	The environment should clearly define and articulate spaces allowing for clear mapping between the users conceptual and physical views.
C6	The environment should allow for features to emerge through use allowing for a range of tasks and ways to complete tasks.
C7	The environment should provide a range of clear and relevant landmarks to aid in orientation.
C8	The environment should provide a range of functionally relevant paths that are clear to the user and integrated with other aspects of the environment and user tasks, thereby promoting awareness.

Table 5-1: The list of ENISpace concepts.

5.3 Overview of Study

The following study is used to demonstrate that (1) there us a transfer of knowledge between real and virtual environments (2) the concepts can be provided in useful guides and (3) the guidelines are useful for the evaluation of electronic spaces. This is achieved through an analysis of the types of issues identified by the evaluators and where the issues were being identified. The study also examines issues relating to the guidelines and the software.

5.3.1 Subjects

The participants in the study were all fourth-year undergraduate students undertaking a module in human-computer interaction (HCI). The group consisted of 17 participants who all had experience of other methods such as Heuristic Evaluation and Cognitive Walkthrough. In addition, they had received at least one lecture on the subject of navigation within information spaces. Although the subjects received no payment for taking part, they did receive credit towards the HCI module.

5.3.2 Equipment and Software Used

The study used two pieces of software, ENISpace (described in Chapter 4) and The Glasgow Directory (described in detail later in this chapter). As previously indicated, (see Chapter 4) the version of ENISpace used is incomplete. However, it does contain all the key features required to undertake the study, such as the ability to enter data, supporting documentation for each guideline, a basic reporting system and the ability to load and save evaluation data. Therefore, although aspects of the interface and certain features are incomplete this does not materially affect the evaluator's ability to carry out the evaluation

5.3.3 Procedure

The participants were asked to evaluate the Glasgow Directory using the ENISpace software. They were then asked to provide a printout of the data obtained, a summary report of their findings and comments on the software. They were not restricted in any way beyond the time limit given to them for completion of the assignment.

5.3.4 The Glasgow Directory

The Glasgow Directory was developed by Strathclyde University and The Lighthouse. It provides the local population, tourists and other people with information about Glasgow. The system is an integrated environment that requires a display resolution of 1024x758 at 16-bit colour depth (minimum), it runs in a standard web browser and includes 3D representations of buildings, a map view, and a variety of search options.

The Glasgow directory provides detailed information on 25 square kilometres of the centre of Glasgow. The directory provides detailed information on specific landmarks, buildings and attractions through a variety of search options. The directory also provides an interactive map, 3D view and photographic images of building exteriors. All features in the Glasgow Directory are linked, for example, a user can click on a search result and have a photograph of his or her selection displayed or visit it in the 3D model.

The Glasgow Directory consists of six screen areas (see Figure 5-1). These are (clockwise from top left) (i) the interactive map, (ii) a building description complete with photograph, (iii) interactive 3D VRML world, (iv) the category search, (v) street finder and at the bottom of the screen, (vi) various user options. One of the principal aspects of the environment is to allow users to locate or search for a variety of attractions using various search methods.

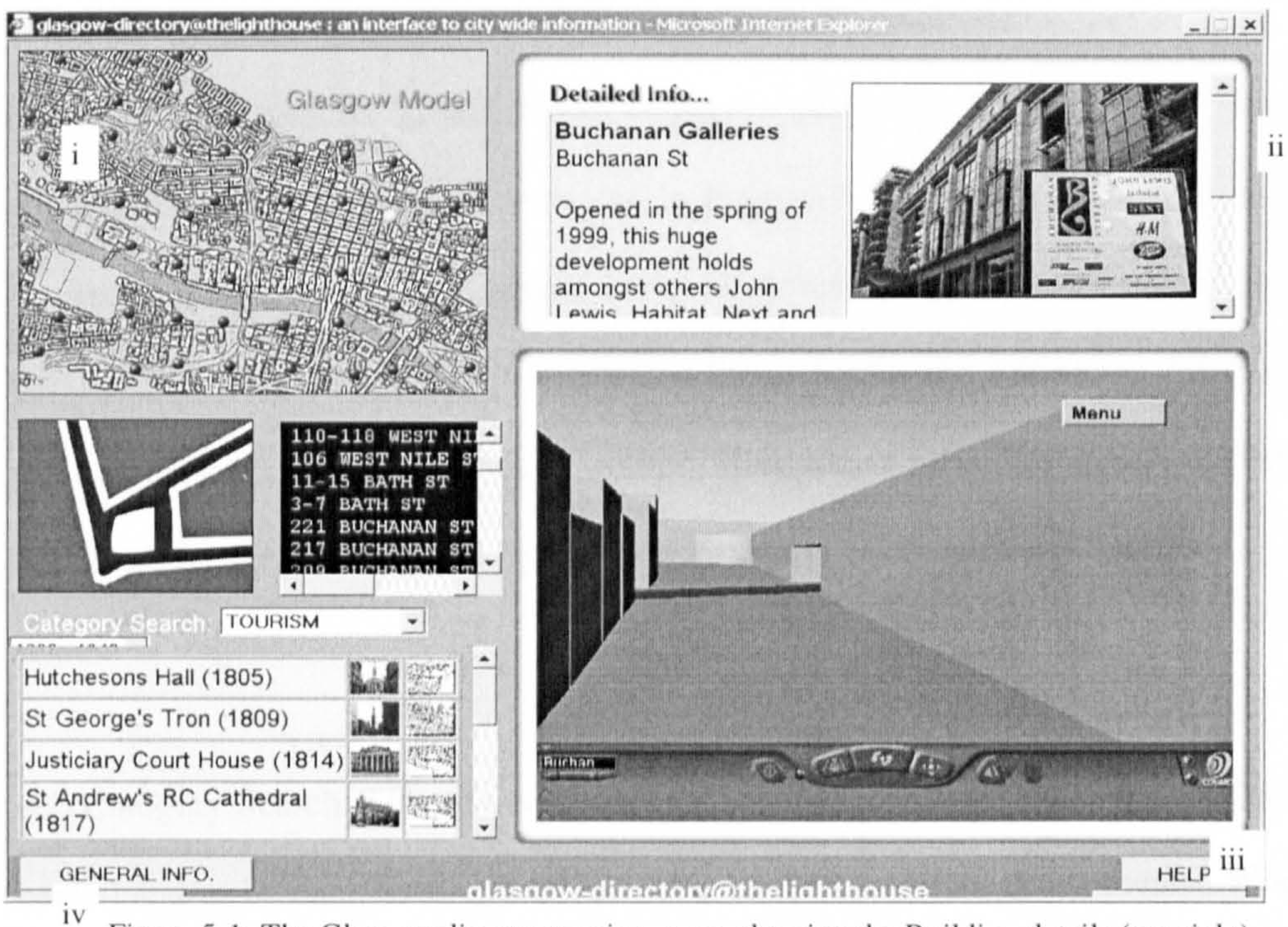


Figure 5-1: The Glasgow directory main screen, showing the Building details (top right) and the corresponding area in the Quicktime VR model.

(i) Clickable Map contains a number of small dots, each one representing a tourist attraction on which the user can click. The VRML world and building description displays are updated to represent what the user has selected. If the user has already selected an attraction based on one of the other search options it is represented as a yellow dot whereas those not selected are red.

(ii) Building Details. This option displays a small piece of information about the selected building, a photograph and in addition (where available) a link is given. If the link is selected, then the QuickTime VR model (QTVR) of the selected building interior (see Figure 5-4) will be displayed. This QTVR model is displayed in the screen area where the still picture was displayed and the user navigates around the model using mouse and keyboard.

(iii) The Interactive 3D VRML Model displays a plan view of the region (Figure 5-1, additional specific pictures are provided in Figures 5-3, 5-5). From here the user can fly into the region and walk around using keyboard or mouse. In addition, a small pop-up menu is provided which displays a list of landmarks within the 3D model. If the user selects one he or she automatically transported to it. The region displayed is based on the options selected by the user from the clickable map, category or street search.

(iv) Category Search. This option allows the users to search for buildings by type (e.g. banks) and/or by date; both options are selected from two pull-down menus. When the query has been executed the results are displayed below the pull-down menus. The user can view the building in the context of the full 3D region (iii) and/or view the building details (ii). Once the building has been selected, the content of the interactive map, street finder, detailed building view and interactive 3D model are modified accordingly.

(v) Street Finder allows the user to search for a specific tourist attraction (not individual street names) and displays information on the attractions within that particular street. If the user selects an attraction, then displays in other parts of the

Glasgow Directory are updated.

(vi) User Options (Figure 5-2). The main option provided by this panel is the database search option which allows the user to search for building, architects and streets within the city. The user can click on the displayed results and the street finder, interactive map and 3D model are updated accordingly. The database option also allows the user to jump to certain attractions using links that are provided in a pull down menu.

The interface also consists of a number of other panels including the Glasgow Directory symbol situated to the left of the street finder; although this consumes a substantial amount of screen space it provides no functionality. In addition, due to the restriction on screen real estate various panels within the browser change function

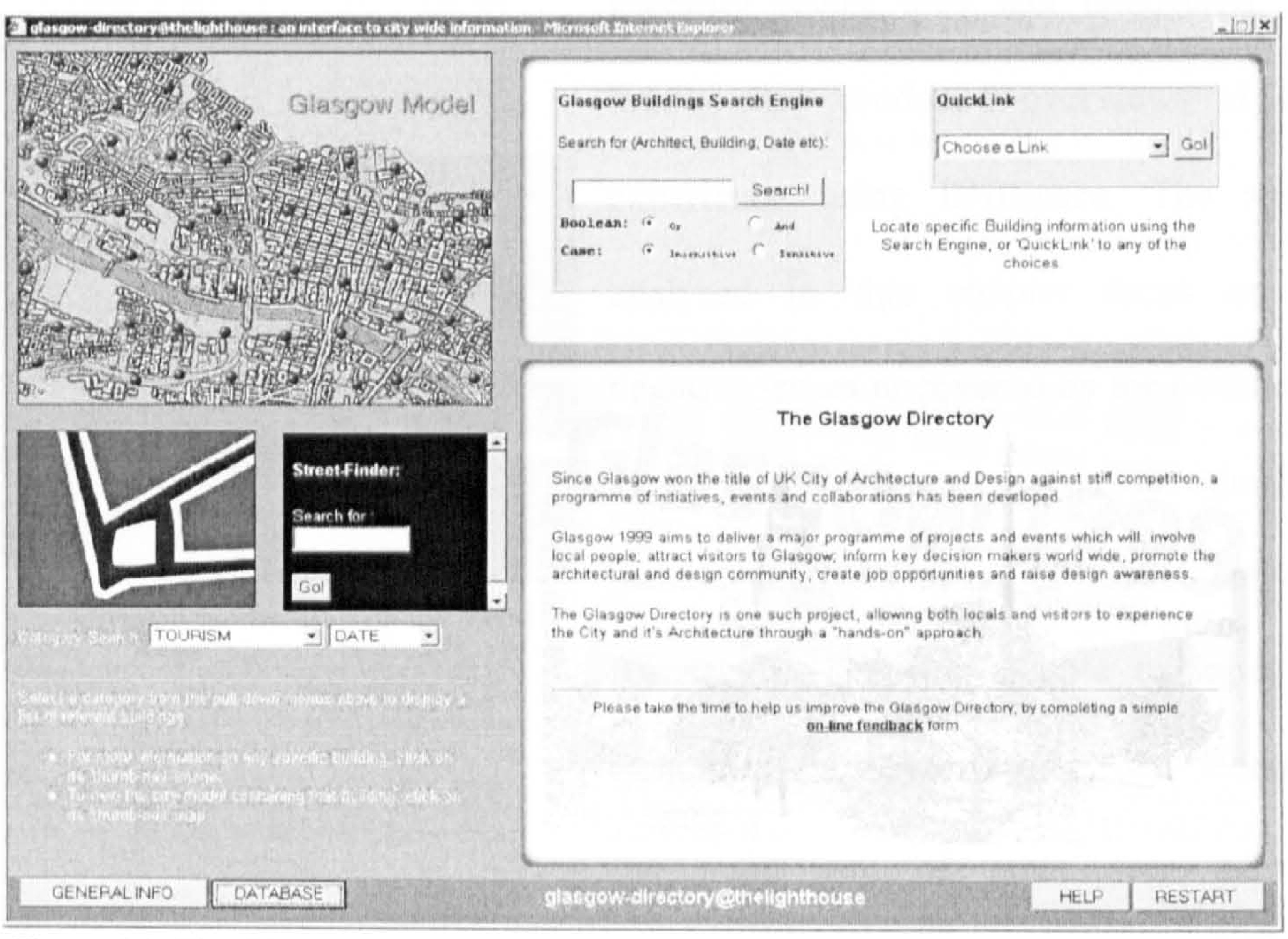


Figure 5-2: The Glasgow Directory. The database options for finding a building and going to a QuickLink are shown top right. The lower left area illustrates the welcome panel.

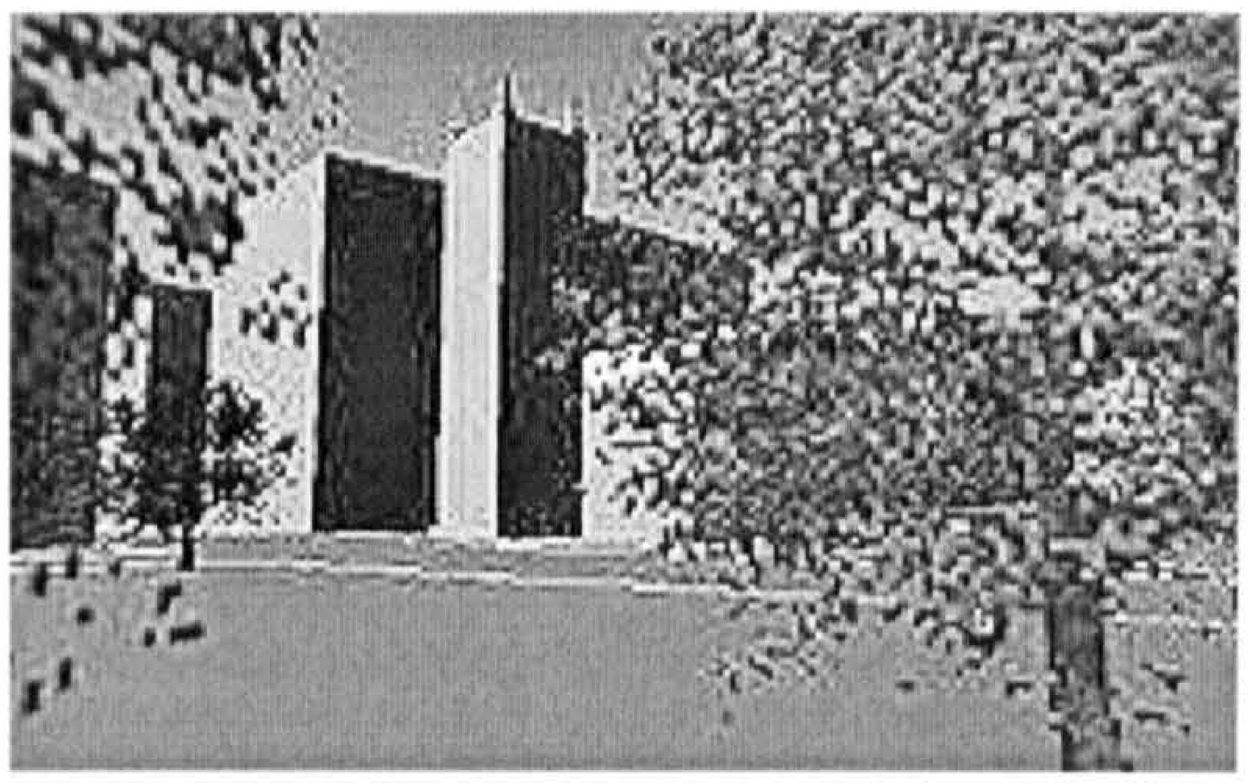


Figure 5-3: A typical view of the inside of the VRML world as seen by the users.

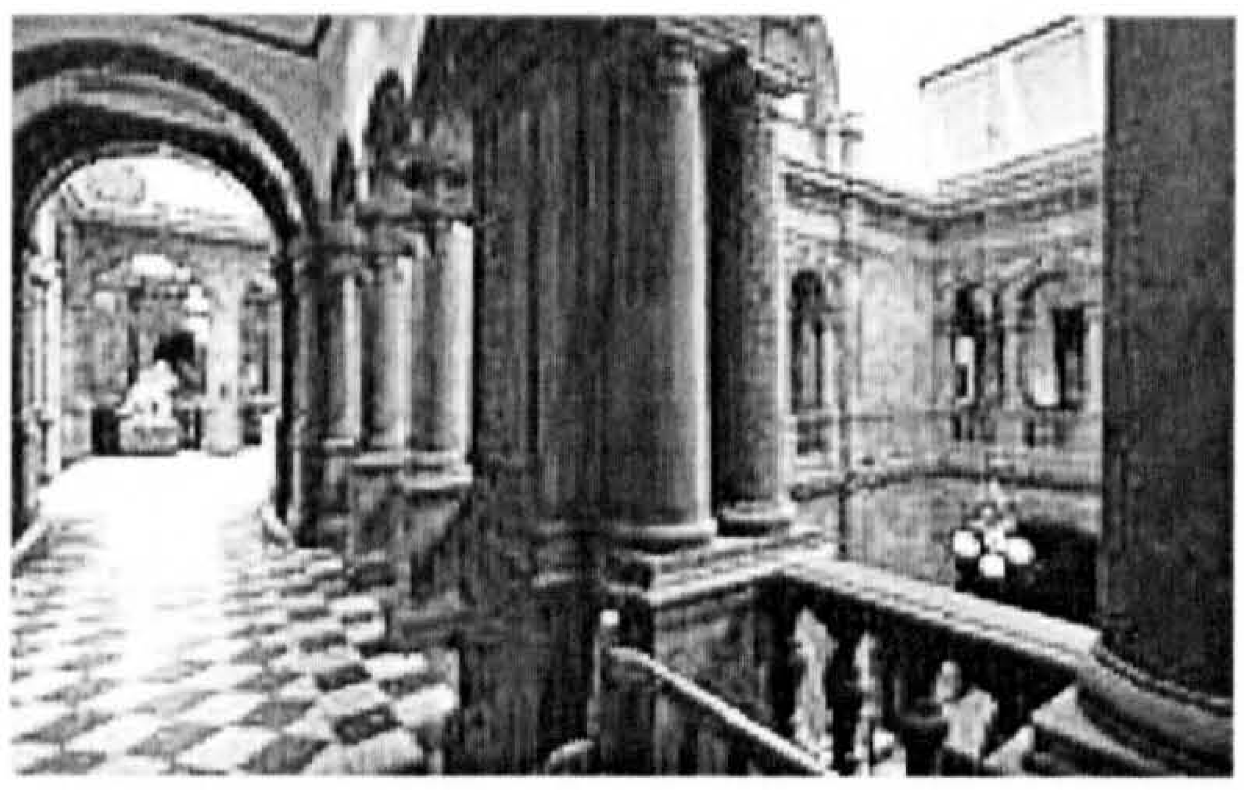


Figure 5-4: Inside a QTVR movie of Glasgow City Council Chambers.

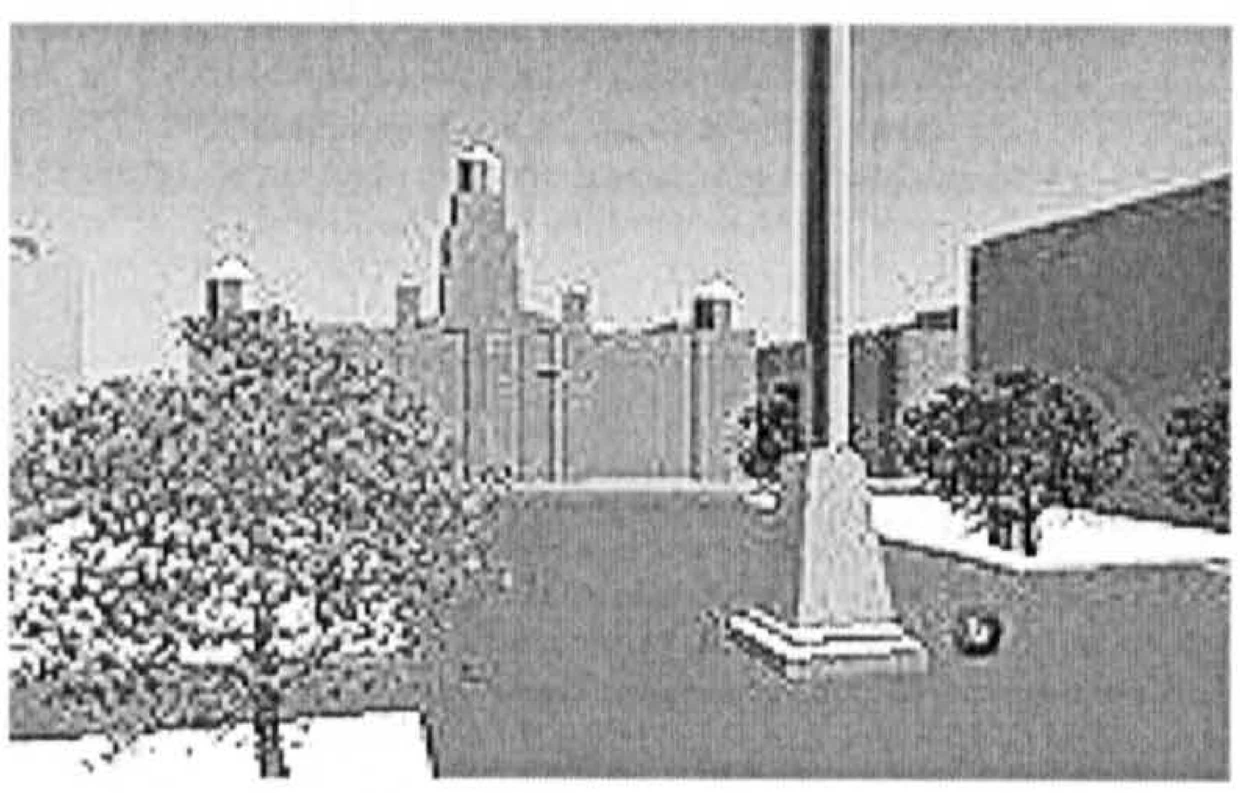


Figure 5-5: A typical landmark with the VRML model.

depending on the options selected by the user.

5.3.5 Data Analysis Method

The students were asked to produce evaluation reports on the Glasgow Directory, and the data obtained by the students was presented in a variety of ways. First, all students produced printouts of the data produced by ENISpace, some are included in Appendix B. Secondly, they provided summary reports that highlighted the main usability issues they had uncovered, and finally they produced overviews of their experience using ENISpace. The results analysed in this chapter focus on the negative issues uncovered by the evaluators. There are two main reasons for this: first, the user interface of the ENISpace software focuses on allowing people to input the frequency and severity of errors. Secondly, the main aim of most user interface evaluation methods is to uncover problems with an interface that may affect usability.

The first stage of the analysis examined what usability issues ENISpace uncovered, which guidelines are highlighting specific problems and the usability of the method. This was carried out by examining the student comments in relation to each guideline. For each issue a record was kept for the number of times it was highlighted. By analysing the comments, it is possible to establish the types and frequency of issues. In turn, this allows the analysis of the comments from the perspective of seeing whether the evaluators are examining the broad themes within ENISpace. Therefore, it is possible to take these general issues and see whether evaluators regard them as affecting the user's ability to navigate. By analysing the types and frequency of the comments it is also possible to examine whether the evaluators understand the correct meaning of each guideline. The example (Table 5-2) provides a range of issues within the Definition of Space guideline and illustrates that the majority of comments were relevant to definition. For example, it was noted that there were problems for new users in defining spaces, however, one other evaluator commented that spaces were clearly defined. From the list of comments provided it is obvious that there is some overlap in issues between signs and defining spaces and that in some cases the evaluators were perhaps misunderstanding the guidelines. It should be noted that the comments are summaries of those contained within the evaluators' reports and not exact copies.

The second stage of the analysis involved examining the summary reports produced by each evaluator and taking a note of the usability problems they highlighted. These issues were then matched with those found in the raw reports. By matching the two sets of data it is possible to ascertain whether the issues uncovered within the guidelines were being considered as usability problems (i.e. found within the evaluators summary).

Within the following chapter, guidelines will be referred to either by name and/or number. Please refer to Appendix A for a complete list of the guidelines.

8	**Definition of space**	Problems for new users defining each space. Signs clearly marked (2). Spaces are all clearly defined (2). Signs on own not good, combined effects enhance definition. Difficult to see balloons in VRML view. VRML: info signs help to define street name finder space.

Table 5-2: An example of the responses given in relation to each ENISpace guideline.

5.4 Results

ENISpace identified 29 general usability issues. Although there is some overlap between certain ones. Table 5-3 provides information on the number of instances of each issue in relation to the summary reports (S), frequency in relation to the guidelines (F) and the number of different guidelines in which that problem appeared (G). Based on the values of S, F and G, Table 5-3 provides an indication of the eight most common issues highlighted by evaluators. The premise within this part of the analysis is that a usability problem is more relevant or serious based on the number of instances within the evaluators' summary reports (S). A problem is also deemed more relevant and serious based on the number of times it is identified within the guidelines (F) and to a lesser degree when examined in relation to the number of different guidelines under which it was identified.

	Issue	S	F	G
1	Lack of Signs/ Poor Quality of Signs/Signs being obscured.	15	53	21
2	No Landmarks or little detail / no buildings of interest marked.	10	28	11
3	Lack of Details / Buildings difficult to distinguish /Buildings need texture.	9	41	14
4	No back option.	14	12	9
5.	Several spaces are hidden / Spaces often share same area.	11	15	9
6	No indication of Direction / Problems maintaining directional orientation.	5	20	8
7	Approach and arrival not clear.	2	17	7
8	Lots of functions stop short of what is expected (clear mapping).	1	14	11

Table 5-3: Eight most frequently identified issues within the summary reports (S), total instances in all guidelines (F) and the number of guidelines in which the issue was identified (G).

5.4.1 Issues Highlighted in the Summary Reports

5.4.1.1 Lack of Signs / Poor Quality of Signs / Signs Being Obscured

"Some informational signs are not visible so the names of the information spaces do not show up at the start." (Evaluator 7, guideline: Visibility of Signs.)

"There should be signs in the world that would support easier navigation." (Evaluator 14, summary report.)

Signs are an integral part of the urban environment and play an important role in helping people navigate, enabling them to find information and warning them of any dangers. Results from this part of the study indicated that where there is a lack of signs, the signs are obscured or the signs are poorly implemented users will experience problems; providing validation of ENISpace concepts C1 to C3. In total, 15 of the 17 evaluators indicated that this was a severe problem in their summary reports and it was emphasised within 21 guidelines on 53 separate occasions. Problems were found across all three sign types (directional, informational, and warning and reassurance). The Glasgow Directory used coloured balloons to indicate the type and location of a destination; a destination being something for which the user was searching. However the design and placement of the balloons was wholly inappropriate as they were frequently obscured, no key was provided to indicate what the colours meant, and when travelling towards the balloons they would become smaller. The latter problem confused many users as this is the opposite to what would happen in the real world.

5.4.1.2 No Landmarks or Little Detail / No Buildings of Interest marked

"The landmarks in VRML are hard to distinguish from other buildings." (Evaluator 5, guideline Landmarks and route awareness.)

"Once within the VRML information space landmarks are not clearly separable from other objects." (Evaluator 5, guideline:Landmarks Clearly separable from other objects.)

"When the model is loaded up there are no landmarks highlighted [...] just a group of buildings which don't symbolise what type of streets and landmarks." (Evaluator 7, summary report.)

"In 3D the image structure is not always recognisable." (Evaluator 14, guideline: Clarity of Function and Content.)

The use of landmarks in the built environment helps people in their creation of environmental knowledge. The results indicate that where a virtual environment does not contain landmarks or mark buildings of interest, problems will be encountered. This view was shared by 10 evaluators, 28 times and within 11 separate guidelines, which highlights the relevance of considering landmark design and placement issues.

Comments from the evaluators indicated that clear and legible landmarks should have been provided (validating concept C7). As this was not the case the evaluators felt it did not match with prior user experiences of the built environment (concept C4) and consequently found it more difficult to map the environment into a coherent structure (concept C5). The evaluators also pointed to problems of being aware of how far along a route they were and that this was caused due to a lack of clear landmarks (P23). Further problems with landmarks were found owing to their poor visibility and separability from one another (P16), no clear indication of landmark function (P18) and key landmarks were not enhanced in any way (P22). The relationship between signs and landmarks was emphasised by the evaluators who indicated that there was a lack of informational signs supporting landmarks (C2). This issue was found under the guidelines relating to the unique marking of objects (S34) and level of signage (S16).

5.4.1.3 Lack of details / Buildings difficult to distinguish / Buildings need texture

"Buildings should be colour coded to distinguish them from Landmarks" (Evaluator 7, summary report.)

"All buildings in the VRML model are grey, it is impossible to know what you are looking at." (Evaluator 8, summary report.)

In order for people to navigate effectively it is preferable that an environment contains buildings or features that are easy to distinguish from one another. Where features in an environment are overly similar people will typically experience navigational problems. This view was shared in 9 summary reports, and on 41 occasions within 13 guidelines.

Feedback in the summary and raw reports indicated that the evaluators experienced problems owing to lack of colour and textures, which made it difficult to identify areas, buildings, paths and routes within the VRML model. In addition, the lack of signs or poor quality of signs provided made identifying aspects of the VRML model confusing. The range of problems led one evaluator to question whether the VRML model may cause people to become more confused when they are navigating within the real City of Glasgow. As a result of the problems, the evaluators concluded that there was poor definition and articulation of spaces (concept C4), there were problems with creating a mental map of the environment (concept C5) and that there were significant problems when attempting to use paths and routes (concepts C8 and C1).

5.4.1.4 No back option

"[In the information display space, the user] cannot go back to previous information displayed." (Evaluator 9, summary report.)

"[In the database search, the user] cannot go back to the previous space." (Evaluator 9, summary report.)

"There is no way of getting back [in] the 3D information space without navigating through the route I previously took" (Evaluator 15, summary report.)

ENISpace concepts C1 and C8 address issues relating to the provision of paths and named routes. In addition, ENISpace also indicates that when designing an environment it is important to consider prior user experiences, this is emphasised in concept C7 and guideline P14. Problems with there being no back button/option were indicated in 14 summary reports, on 12 occasions under 9 different guidelines. The responses in relation to this issue indicate that there is a need for a separate guideline on providing a back option.

The evaluators highlighted a number of usability issues within the whole environment and individual spaces. Problems were found in relation to the QTVR model which once activated did not allow for an easy way to go back, either within the model or to the previous interface state. These particular problems were uncovered within the conceptual and physical guidelines and within the signs section. The specific comments were made in relation to the provision of clearly marked paths (P26) and the marking of optimal routes (S19) guidelines. Additional problems were apparent within the VRML model and database search, with a number of evaluators indicating that the changing screen spaces did not allow for an easy way back to previous options or information.

5.4.1.5 Several Spaces are Hidden

"The space is regularly invaded with different information." (Evaluator 13, summary report.)

"In some cases another information space is destroyed and replaced by something new." (Evaluator 14, guideline: Clear Approach.)

"The designers have compromised screen space by hiding some information spaces and sharing screen areas." (Evaluator 17, summary report.)

The problem of screen spaces being hidden or unexpectedly changing was highlighted in 11 summary reports, 15 times and on 9 separate occasions, a typical example being the database search tool, which is often hidden by other options. As is evident from the example comments, the evaluators experienced a range of problems and considered the constantly changing screen spaces as an issue which required addressing. This problem is concerned with how the environment clearly defines and articulates the spaces contained within it (concept C5).

5.4.1.6 Lots of Functions Stop Short of What is Expected

"Clicking on the picture you would expect the 3D model to update, it does not." (Evaluator 8, guideline: differentiation in paths.)

The Glasgow Directory contains a large number of ways to search and interact with information. However, some functions suggest that a specific task will be completed but the outcome varies from what is expected. Although only one summary report mentioned this problem it does appear on 14 occasions under 11 separate guidelines. A typical example of the problem is when a using the street finder tool, in this case the user is taken to the VRML model to view the result. Under normal circumstances it would be expected that the user would be taken to the required destination, instead they are taken to the general area where the destination is located and must then find it by themselves. This conflicts with many of the concepts within ENISpace in particular making the destination of routes clear as well as any supporting signage (concept C1).

As a result of this a number of evaluators commented that they had problems in conceptualising the overall space (concepts C4 and C5).

5.4.1.7 No indication of direction /Problems maintaining directional orientation

"It is hard to tell which is North, South, East or West." (Evaluator 13, summary report.)

"It should be noted that the North, South, East and West metaphors are missing." (Evaluator 17, summary report.)

The provision of clear directional information is vital to the navigability of any environment (concept C1). Findings in this area primarily related to the lack of signs to help people in their navigational tasks, although the problem was also highlighted to a lesser extent within the conceptual and physical structure guidelines. This issue was uncovered in five summary reports, on 20 separate occasions and under eight guidelines. The areas of concern ranged from lack of cues to support specific routes to structures to help in gaining overall directional orientation (S15). The environment contained no North, South, East or West indicators which therefore made it very difficult for people to gauge their locations or directions of movement. Other problems were lack of clear symbolic or language (S11, S12) metaphors within signs, lack of provision of Distance or Time information (S14) and an inappropriate number of signs (S16).

5.4.1.8 Approach and arrival not clear

"I felt that this was not achieved well." (Evaluator 14, guideline: clear approach.)

ENISpace highlights the importance of clear path and route structures from the perspective of signs or cues (concepts C1 and C6 to C8). The issue of poorly implemented approach and arrival cues was highlighted in two summary reports, 17 times under seven guidelines. The majority of issues uncovered were within the VRML model and ranged form problems with signs to the underlying structure not making approach and arrival clear. Signs were illegible, not provided or did not provide enough feedback, therefore making it unclear when a user initially encounters a route and similarly on approach to a desired destination.

Visibility of signs
Balloons are obscured by buildings (2).
Red arrows are not always visible.
When using the street finder there is no sign that tells the user to input text words.
Informational spaces (and signs) not always visible, this is not a bad thing and is done to reduce memory load.
Visibility of Environment
VRML: menu obscures information.
General information button brings up directional and informational signs, which can obscure objects.

Table 5-4: Comments made by the evaluators in response to the visibility of signs and environment guidelines.

5.4.2 Issues Identified Within the Guidelines

The previous section examined the issues identified by the evaluators within the summary reports and to a lesser degree within the individual guidelines. The following section examines the underlying concepts (C1–C8) and how these are validated by the responses to the individual guidelines.

5.4.2.1 General Signs Guidelines

Although the signs section is split into three main areas (directional, informational, warning and re-assurance) there are a range of general issues that apply to all sign types. These include visibility of signs, visibility of environment (see Table 5-4) and consistency of design within individual sign types as well as inconsistency in appearance from other sign types. Other general aspects include the definition and articulation of spaces through the use of signs and metaphors to convey information.

Although the evaluators experienced some problems in correctly interpreting the meanings of the guidelines, a number of relevant issues were uncovered. These included problems navigating in the VRML world due to the signs not being differentiated in any way, and the positions and colour of signs.

The evaluators had virtually no problems correctly understanding the meaning of the definition of space guideline. Typical issues raised included difficulties in understanding what each space does and lack of markings within the VRML world. There was also a range of positive comments suggesting that the signs for different areas of the environment were clear. In addition, the evaluators uncovered a range of issues relating to the use of metaphors within signs (see Table 5-5).

The red dots on the map standing out well for their purpose.
The environment lacking colour metaphors, with the exception of the balloon metaphors in the VRML
The VRML world contained clear metaphors, such as the clouds and sun etc.
The arrows used within the VRML world clearly indicated their purpose.

Table 5-5: Sample responses made by evaluators in response to the various metaphor analysis guidelines.

5.4.2.2 Directional signs

Further evidence for the validity of the signs concepts (in particular directional signs) was uncovered in a series of responses by the evaluators. Within the markings subsection (S14, S15, S18, S19) a range of relevant issues were uncovered. Several evaluators did comment that there was a lack of distance/time cues, with two commenting on this in relation to the VRML world and three in relation to the whole environment.

The results from the clear marking of direction guidelines indicate a range of positive and negative aspects with the Glasgow Directory. These ranged from making direction clear in the entire environment to the need for specific cues within the VRML model Four evaluators commented that there were no markings of optimal routes and there was no back option in the QTVR movie. They also noted that a number of options were available when the right mouse button was pressed within the VRML model and that this option was not immediately obvious. It was also noted that there were a number of routes available to different spaces and at times this may confuse users.

Within the Appropriate Level of Signage, Clear Location Information, and Minimalist guidelines (S16, S17, S21) the responses indicated a range of relevant issues (See Table 5-6). The responses indicate that there is a need to provide an adequate level of signage that contain clear cues, in particular within 3D spaces.

A number of relevant issues were highlighted in respect of the Clear Transition and Clear Marking of Route guidelines (see Table 5-7). Responses to the clear transition guideline uncovered a range of issues such as poor transitions between the Database and Street Finder searches and the lack of details within the VRML model. In response to the Clear Marking guideline, problems uncovered included the lack of markings in the VRML model, lack of clarity on final destination of route and the problem of identifying routes within textual spaces.

Appropriate level of signage
No signs
Would be better to have signs to illustrate relationships between spaces.
No NSEW indicators in the VRML world.
Clear location information
Lack of info in VRML model.
No spaces except Street finder are clear about the location.
Red dots (in map) give street name but not in VRML model, this is confusing.
Minimalist
Balloons are simple (this is good).
Balloons (in the VRML model) are too vague.
Red arrows are meaningless (in the VRML model).

Table 5-6: Responses in relation to the three guidelines indicate their relevancy.

Clear Initial Encounter
No clear indication of new routes (2)
Other ways to find new routes (e.g. search) not initially obvious (2)
Results from the database search do not imply new routes.
Clear Arrival
On arriving in the VRML world after using street finder the user is taken to a portion of the map and not the exact position.
The street finder tool does not indicate if a search is found or not found.
In the VRML world only the coloured balloons give an indication as to arrival.

Table 5-7: Responses by the evaluators in relation to the Clear Initial Encounter and Approach guidelines.

5.4.2.3 Informational Signs

Owing to the nature of the Glasgow Directory there is little scope for the inclusion of signs that provide information on other users or updated information. However, there was some confusion over the difference between an object and a location.

In certain cases the guidelines within the informational signs section contained no responses or a series of invalid responses. However, the feedback in relation to the two remaining guidelines: Marking of Objects and Locations, indicates that relevant issues such as the similarity in buildings and the use of the coloured balloons to mark locations were found.

5.4.2.4 Warning and Reassurance signs

The Glasgow Directory does not need to provide any warning signs. However, feedback from the evaluators did indicate that there was insufficient positive feedback within the VRML model.

5.4.2.5 User experience and requirements

The evaluators indicated there were no problems with the memory load placed on users, and that the nature of the space meant there was no need to provide private areas. However, the evaluators did provide 25 relevant responses when asked to comment on how the Glasgow Directory reflected prior user experiences (a summary is provided in Table 5-8). This clearly indicates that evaluators regard prior user experiences as a relevant issue when designing an environment.

Relate to User Experiences
Assumes prior knowledge (3).
No way to go back to previous building in information window (unlike web browsers).
When the user moves between different locations the translation is different from navigation in the real world, this may make it more difficult to build up survey knowledge.

Table 5-8: Responses Relate to User Experiences guideline clearly indicate the relevancy of this guideline.

5.4.2.6 Definition and Articulation Spaces

The first guideline Define Important Spaces, directs designers towards the use of spatial layout to enhance the understanding of the environment. The evaluators identified a number of relevant issues, for example areas of interest not being marked on the map, an which has no purpose object appearing to be important and important objects not being clearly marked (See Table 5-9).

Define Important Spaces
Map has no indication of hotspots of interest.
The [...] crossroads lacks function yet is clearly defined for no reason.
VRML: Colour of menu buttons blends with buildings so it is easily missed.

Table 5-9: Responses to the Define Important Spaces guideline indicates the importance of providing clear cues to indicate what is important and what is not.

There was an overlap with issues previously highlighted in relation to the similarity of the buildings in the VRML model. In response to the Define Spaces with Different functions or requirements guidelines several evaluators appeared to be providing responses similar to those that also arise in the define important spaces guideline (P4). However, the responses were broadly relevant to the intended definition. Similarities included problems with changing or overlapping screen areas and using the category search. Other common themes related to lack of clarity of functions, the level of functionality provided by options, types of functionality provided by objects and differentiation between different options and functions. The evaluators were asked to comment on whether the environment had clearly defined spaces with related functions. The responses clearly indicate that the evaluators felt this guideline was a relevant issue when examining the layout of a space (see Table 5-11).

The evaluators were asked to comment on the emotional feel of the current Glasgow Directory. Reponses to this guideline indicates that emotion is a relevant aspect within interface design. The final guideline in this section relates to the mapping between the physical and conceptual views of the space. Nearly all responses to this guideline were relevant to its intended area of assessment and highlighted genuine usability issues.

Clearly Define Spaces with Related Functions
Relationships (between spaces) are not clearly defined (2)
Grouping is clumsy.
Users may think that VRML view will update street finder and category search but this is not the case.

Table 5-10: The comments in relation to the Defining of Related Functions points to the importance of providing clear grouping and definition of related objects or features.

Mapping Between the Physical and Conceptual Structure
VRML view not good.
At first, the relationships between the 2D and 3D representations are not clear.
In the street finder, the user expects to be able to locate streets especially inside the VRML world (this does not happen).

Table 5-11: Sample responses from the mapping between Physical and Conceptual Structure guideline indicate this is a relevant issue.

5.4.2.7 The Environment Should Allow for a Range of Tasks and Ways to Complete Tasks

Emergent Opportunities
Some features, especially the Street Finder are hard to find.
Interface can quickly show too much information, causing information overload (2)
Some options unfold with use (2)

Table 5-12: Responses to the Emergent Opportunities guidelines point to the need to consider the rate at which options become available.

There were problems interpreting some of the guidelines relevant to this concept. Problems were found with mutually exclusive spaces being placed near one another, for example, the date and category search are not related despite the fact that their close proximity would suggest otherwise. Another example was the placing of the database search tools inside the help area. The evaluators indicated a number of positive and negative issues relating to emergent opportunities (see Table 5-12). Although the evaluators had some problem in correctly interpreting the meaning of the variety and robustness guidelines, they did highlight a range of problems. One of the most common issues highlighted was that spaces frequently changed appearance and that this may confuse users.

5.4.2.8 Landmarks

Although there were substantial problems with the evaluators identifying exactly what constitutes a landmark they did highlight a number of relevant issues. The main aspects uncovered (as is also reflected in the summary reports) were that there simply was not enough detail to indicate what constitutes a landmark (see Table 5-13) and as a result there were navigational problems.

Further evidence for the relevancy of considering landmarks was provided in relation to the Landmarks and Route Awareness guideline (P23). This clearly indicates that a landmark must promote awareness of the overall route structure. As a result, there were problems with route awareness within the VRML model.

Landmarks
Not easy to identify individual landmarks (2)
Colour balloons are not good (2)
Problems distinguishing landmarks (3)

Table 5-13: Some sample responses from some of the Landmarks guidelines. They indicate the confusion in what are landmarks and also poor implementation of items that are considered landmarks.

5.4.2.9 Provision of Path structures

The guidelines in Table 5-14 focus on the use of cues to mark paths, to differentiate them from the general environment, and to provide consistent marking so that the user can be aware he or she is in a specific path. The evaluators commented that a number of problems existed owing to the lack of clear path markings, in particular within the VRML world, where there were no specific paths or signs provided. Similar problems were found in relation to the differentiation in paths and the Clear within Path Markings guidelines. Issues uncovered included the lack of clarity for paths between information spaces, problems with lack of path markings in the VRML model and no differentiation between paths within the VRML model.

Responses provided to the Clear Initial Encounter, Approach and Arrival within paths guidelines (P34 to P36) clearly indicated that the evaluators considered these relevant issues. For example, they noted the Clear Initial Encounter opportunities provided by the Street Finder. They indicated that the lack of path structures would be especially confusing in the VRML model, particularly to those without prior knowledge of Glasgow. Problems were uncovered with the Building Selector in that it provided no path structure. Therefore, users had problems knowing how far they were into completing their tasks. There was some overlap in responses within the Clear Approach and Clear Arrival guidelines with four evaluators highlighting problems with the whole environment not providing clear arrival information. In response to whether there were clearly marked paths within the environment the evaluators indicated a range of problems, including the environment not containing any shortcuts to different spaces. Problems also arose in relation to the link provided within the results from the database search and the maps, in particular the way in which the user is taken to a region on the map not the selected building.

Differentiation in Paths
VRML world has no coding to aid in identifying paths.
No clear paths between information spaces.
Routes are more clearly defined than paths.
Some of the paths in menu model are not clearly marked.
Clear Within Path Markings
Most except VRML clear.
Easy to follow, clicking on one path will lead to another.
Building selector: no info displayed until criteria setting path is followed. After this point no markings displayed.
Street finder: not clear which paths are links to more information or functions.
VRML: no paths, hence no differentiation can take place.

Table 5-14: Responses to the guidelines in the above table clearly indicate that problems are being encountered when paths are not differentiated or marked.

The guidelines on path and route structures (P25-P33) examines the relationships between the paths and the wider environment. When asked if the path structures integrated with signs, problems were highlighted, such as the lack of signs and problems within the VRML model. The evaluators indicated that although some features of the environment did become apparent to them as they moved around, some important aspects remained hidden and this resulted in problems. Typical examples included information on areas of interest around the selected streets and the helicopter within the VRML model.

5.4.3 Areas for Improvement within the Guidelines

The results from the study found that ENISpace did identify a range of relevant usability issues; however there were problems with the guidelines. The problems stemmed from ambiguity in the wording, the very subtle differences between concepts, terminology and links between related guidelines.

5.4.3.1 Guidelines which Require Rewording, Linking and Grouping

From the responses in relation to Visibility of Environment (C5) and Visibility of Signs (C4) it was clear that evaluators were confused by the idea of making signs visible while not obscuring the environment. Similar problems were also noted in respect to the Consistency and Inconsistency of Signs guidelines (C6, C7). Therefore, it would appear that there is a need to reword and/or integrate these guidelines. In both cases clearer supporting documentation will reduce the problem of interpretation.

There was some overlap in the responses to the following guidelines: Appropriate Level of Signage (S16), Clear Location Information (S17), Clear Mapping (S20), Minimalist (S21) and Dynamic Information (S22). This would point to the need to remove any ambiguity between the different guidelines and to provide better definitions. Further problems in correctly interpreting the meaning of the Dynamic Information (S22) and Clear Mapping (S20) guidelines were found, which indicates the need to improve the wording and definitions of these guidelines.

The Route Monitoring guidelines cover aspects of sign design, which indicate to the users their positions within a given route (or task structure). The guidelines consist of providing Clear Initial Encounter (S23), Approach (S24) and Arrival (S25) cues. Although the evaluators highlighted relevant issues within each of the guidelines there was a degree of confusion regarding the various stages of the routes. This would point to the need to provide clearer guidance or to merge the guidelines.

A number of guidelines within the signs section did highlight relevant usability problems however the spread of results indicates there is a need to provide clearer wording and supporting documentation. These include the Language Metaphors guideline (S12), aspects of directional signs such as the ability of users to orientate themselves within the environment (S26) and whether the signs are Appropriate for Users (S30).

The opportunities and activities section of ENISpace examines the provision of features within the environment, in particular, the Variety of Options (P9) and Robustness (P11). In addition, several other aspects are examined, including, the degree of Emergent Opportunities provided (P2) and the level of Mutual Exclusion (P8). These guidelines deal with the degree to which options gradually unfold to the user and whether certain objects should *not* be placed next to one another. Overall, the evaluators succeeded in highlighting a range of relevant issues across all these guidelines. However, comments indicate that there is a clear link between themes in this section and within the Definition and Articulation guidelines. However, there were problems in interpreting the difference between variety and robustness. As a result, there is clearly a need to provide more appropriate wording for these two guidelines, which at present are exactly the same as the terms used in architectural design.

The evaluators had problems in agreeing on what constituted a landmark but still managed to uncover relevant issues. They also provided responses that overlapped to some extent with those found in the definition and articulation guidelines. Therefore, there is clearly a need to examine more carefully the aspects of landmark design and the links between landmarks and the wider environment.

The paths guidelines were correctly interpreted on most occasions and a number of relevant issues identified. One of the main problems was that the evaluators were not able to correctly understand the meanings of the various stages of a path and, therefore placed results under the wrong guideline. A typical example is confusion among Clear Initial Encounter, Clear Approach and Clear Arrival as well as aspects of providing awareness of features and Emergent opportunities.

5.4.3.2 Guidelines That Have Not Been Validated in This Study

The study did not test for aspects of collaborative systems, therefore the guideline on Other User Information (S32) could not be tested. The evaluators did not provide enough or any responses to a range of other guidelines including Articulation of Space (P9), the Provision of Warning Signs and the level of integration between paths and the environment (P31) and Easy Exit (S28).

The nature of the Glasgow Directory is such that most options require very few steps and there were no responses in relation to the guidelines on providing information about Alternative Routes (S18), Optimal Routes (S19), Direction (S15) and Distance and Time (S14).

As has been indicated earlier the evaluators experienced problems in defining what constitutes a landmark. This may have been a contributing factor in the lack of responses to the in relation to the Gestalt concepts (P24), Allow Orientation (P16) and are Relevant for Users (P21) guidelines.

5.4.4 Usability of the ENISpace Software

Although ENISpace identified a range of relevant issues, there were a number of problems with the software. The evaluators noted that the ratings only allow negative responses and therefore can only be used to document problems not positive aspects of an interface. They also noted that it is sometimes difficult to assign a score to the frequency and severity of an error. Another problem was that they would prefer to avoid guidelines that are not relevant rather than still have them displayed on screen.

In terms of the software, there were very few criticisms of the overall usability. The poor quality of the icons is as a direct result if having to use the standard ones provided with Microsoft Visual Basic and it is acknowledged they are not always suitable. The main criticisms of the software concerned the amount of data produced by the report generator, the layout of the reports being poor, the bugs in the software and the poor quality documentation. Evaluators noted that the overview structure (maps) of the information made navigation within ENISpace easy. Many evaluators noted that a lot of the guidelines appeared related but this was not always obvious (the only method of linking them was provided via the built in documentation).

There are a range of improvements that could be made to the software, particularly ways to improve the relationship between the aspects of the interface being evaluated and the data being input into the system. This could be provided by an interface profile mechanism that creates a relevant set of guidelines based on the software being evaluated. It may also be possible to provide a way of linking the method of assessment to specific aspects of the interface. For example, the software enables the evaluator to select a part of the interface then assign individual guidelines, ratings and comments to that particular object or area. The analysis revealed that the evaluators relied more heavily upon the comments rather than the ratings they assigned to specific guidelines. Therefore, any future versions should provide a better structure for supporting the comments entered by the evaluators. In general, there is also a need to improve the quality of the online documentation and create a method of linking related guidelines together; this would hopefully avoid too much repetition of information and reduce the amount of time spent carrying out the evaluation. The concepts within ENISpace are designed to examine navigation from an overall perspective and be applicable across a range of interfaces; one possible method of overcoming some of the issues may be to provide an online library of past experience similar to the idea proposed by Henniger, Lu & Faith (1997). This would allow a body of knowledge of past experience and evaluations to evolve over time.

At this stage it is probably not beneficial to discuss the individual guidelines and the re-wording required, but rather to focus on the main changes. It is clear there is a need to reduce the number of guidelines and perhaps to provide a 'lite' version that emphasises key areas. The lite light version would comprise of an extended set of the core concepts (C1–C8). As a result, the evaluators could look up specific information on smaller issues if they wished to do so. One of the first aspects to change would be merging apparently conflicting guidelines for example, within the signs section integrating the consistency and inconsistency guidelines. This would allow for a closer examination of consistency/inconsistency in general without the need for two guidelines.

5.5 Discussion

The proceeding study has presented two sets of information. First, a list of the eight most frequently identified issues from the perspective of summary reports and second an overview of the responses in relation to individual guidelines. The first stage of the analysis illustrated that the evaluators were uncovering a range of issues, which were related to the underlying ENISpace concepts. The second stage which analysed the responses to the individual guidelines illustrated that the evaluators were uncovering a range of relevant issues.

There is clear evidence from the comments contained within both stages of the analysis that the evaluators agreed with the idea of evaluating the sign design and placement issues. While several of the problems related specifically to the 3D VRML model, many related to how people navigated within and among the different spaces such as the Category Search, Street Finder and Map. Within sign design guidelines relating to the placement, consistency and use of metaphors the evaluators uncovered problems across all aspects of the Glasgow Directory. These ranged from signs not always being visible in the VRML model to aspects such as there being poor metaphors within different spaces. There was a range of issues highlighted in relation to the three sign categories in both the summary reports and the comments in relation to specific guidelines. Concept C1 states that directional signs play an important role in the design of electronic environments and the lack of clear directional cues resulted in problems in various areas of the environment. For example, the evaluators indicated that there was a lack of initial encounter, approach and arrival cues, which led to problems with being aware of the range of options within the space. There was also evidence to suggest that informational signs (Concept C2) were not adequately provided, with evaluators suggesting that objects and locations were not clearly marked. This caused problems with not being able to identify buildings in the VRML model and options/objects in the rest of the environment. In this study it has not been possible to thoroughly validate the concept of warning and reassurance signs (Concept C3). This is primarily because of the fact that the environment didn't need to provide a significant number of the latter. However, it was noted that the evaluators felt that navigation in the 3D VRML model was problematic owing to the confusing feedback given while moving through the space.

The comments made by the evaluators provided a strong indication that there is a need to consider the physical and conceptual aspects of an environment. The first concept in this section (C4) relates to providing cues, which reduce memory load, allow personalisation of the environment, relate to prior experiences and allow for a degree of privacy. The comments in relation to these guidelines clearly indicate the relevancy of making evaluators aware of users' prior experiences, an issue that is relevant to the navigational paradigm but also exists within other usability methods. The evaluators also indicated that there were no overall problems with the amount of memory requirements placed on end users but pointed out that this environment did not allow personalisation or collaboration; hence the other guidelines were not relevant. The evaluators also indicated the relevancy of examining the definition and articulation of spaces (Concept C5) and highlighted a number of problems-ranging from poorly defined spaces to lack of cues showing the relationships between different areas of the space and were problems with the mapping between the physical and conceptual aspects of the space, in particular the 3D VRML world.

ENISpace highlights the importance of an environment that allows options to emerge through use and support of a range of activities (Concept C6). While confusion did exist in interpreting the Variety and Robustness guidelines, the evaluators did identify a range of usability issues such as areas of the environment changing function. Mutual exclusion of functions was also a problem, with many 'incompatible' functions placed next to one another. The evaluators suggested that there were issues associated with the environment not allowing options to emerge over time, in particular options not being clear and their being too many (which may cause cognitive overload).

The final two concepts within the conceptual and physical structure guidelines relate to the provision of landmarks (Concept C7) and paths (Concept C8). While there were problems in defining exactly what constitutes a landmark, it is clear that the lack of landmarks within the 3D model did cause severe problems for the evaluators. They also encountered problems with objects appearing to be important (i.e. seeming to be landmarks but having no function) and the lack of landmarks within the map. The path structures in all aspects of the environment were not appropriate or were poorly implemented. Problems were noted in relation to there not being paths in the VRML model and a lack of clear path cues when moving between different information spaces.

The results from this study shows that most of the concepts (C1,C2, C4–C8) are considered relevant by interface evaluators when evaluating both 2D and 3D information spaces. The concepts are not hypotheses but they do allow for an overview of the core areas to be placed in the context of the overall thesis. As a result, it is possible to conclude that knowledge from the navigational behaviour of people within the real world is applicable to the design and evaluation of 2D and 3D electronic information spaces.

5.6 Conclusions

In conclusion, this chapter has illustrated the validity of nearly all of the ENISpace core concepts (C1–C8, excluding C3). First, a series of general usability problems based on the evaluators summary reports was provided, and as a result twenty-nine usability problems were identified. Secondly, the comments made by each evaluator in relation to each guideline were summarised. Based on these two levels of analysis, and an additional phase of matching the general usability problems with those for each guideline, a further level of analysis is supplied. This provides a way of identifying whether genuine usability problems were being uncovered in relation to each guideline. Moreover, it was possible to ascertain the agreement among evaluators as to its existence by looking at the frequency within the summary reports and individual guidelines. As a result, it is clear that ENISpace identified a range of issues, which in many cases fell under the core concepts (C1, C2 and C4–C8). These include the provision of clear and appropriate signage (C1, C2), clear path and route structures (C1, C5, C6, C8), clearly defined areas of the environment that are relevant to user experiences (C4, C5, C8) and clear landmarks (C7). As a result, from the number of issues highlighted through the use of ENISpace, it is clear that the core concepts (and certain specific guidelines) are more applicable to 3D than 2D information spaces.

As well as the types of usability problems identified this study has also indicated the need to address the usability of ENISpace. Although a detailed reworking of the guidelines is beyond the scope of this thesis it is clear that a number of issues need to be addressed; these include: reducing the number of guidelines; improving the wording; providing a clearer grouping; and providing links between related guidelines. The results also indicate the need to allow for clearer units of assessment, i.e. a method of assessing the environment on a 'per screen' or 'group of screens' basis. Several evaluators also indicated problems with the context of use of sections or individual guidelines within ENISpace. This would suggest a need to provide a higher level profiling system, allowing evaluators to supply key characteristics of the environment, leading a situation where the software only provides them with relevant guidelines. In addition, it is clear from the results that the comments provided by evaluators are currently the most valuable result obtained and the reporting system needs to be redesigned to reflect this.

In conclusion, this chapter has indicated that ENISpace does provide answers to the range of research questions posed within this thesis. One of the main questions being whether there is a transfer of design knowledge between real and electronic spaces. The summary reports and comments made in relation to the specific guidelines provide an indication that there is a transfer of knowledge. Typical examples include the design and placement of signs and paths, the inclusion of specific routes and the consideration required when examining the relationships and grouping of spaces. The second research question 'can the concepts be provided in a series of useful guidelines?' is also validated. Evidence for this is contained through the volume, type and quality of responses in relation to the various guidelines. This was the case even when evaluators had problems in interpreting specific guidelines. The final research question "Are the guidelines useful for evaluation and design of electronic spaces?" is also partially validated. The results indicate that a) evaluators were encountering usability problems as a result of features not being correctly implemented, b) the guidelines did detect a range of problems which may not have been detected within other methods c) they were able to use the guidelines to undertake and evaluation and gain meaningful results.

Chapter 6

Using ENISpace for Design

This chapter presents a study of using ENISpace to design 3D virtual environments. The user study carried out as part of this clearly points to the benefits of the various design concepts and points to the use of cues being dependent upon the type of navigational activity being undertaken by end users.

6.1 Introduction

The following chapter presents a study of using ENISpace to design two 3D virtual environments. The study presents two environments which were built using ENISpace, however, the main focus is on the results obtained from the larger environment. The study takes an exploratory perspective and examines the behaviour of users within the designed environments. Further to this, the study takes a combinatory view when uncovering results by using a range of methodologies. In doing so the study provides corroborating evidence for the findings by examining data from a range of sources.

The purpose of the study is to explore the use of cues by end users within the various environments. As a result it explores the three main research questions: 1) Is there a transfer of design knowledge from real to electronic spaces? 2) Can concepts be provided in a series of useful guidelines? 3) Are the guidelines useful for the design and evaluation of electronic spaces?

In common with Chapter 5 the guidelines within ENISpace will be discussed from the higher level conceptual groupings rather than individually (see Table 6-1). A similar style is adopted with the reporting of the results. As a result the chapter is broken down into the following sections: a description of the method, a description of the results in terms of the exploration within the large environment, a comparison between exploration and wayfinding within the large environment, general results which apply across both environments, and a discussion of the results and the conclusions.

6.2 Method

6.2.1 Subjects

The subjects were recruited by advertising on notice boards and through an email campaign. In total 40 participants took part, of which 24 were male and 16 were female. The subjects were informed that the test would last approximately one hour and received either a payment of £4 (Napier participants) or a free cinema voucher (Swedish participants). The majority of the subjects were students, however there were some members of the public and university staff.

6.2.2 Tools Used and Software

The guidelines from ENISpace were used to construct two 3D environments for teaching schematic modelling to students (Figures 6-1 and 6-2). The environments were built using the Active Worlds system. Twenty-two participants used the large environment (Figure 6-2) and 18 used the smaller environment (Figure 6-1). Both environments were designed to replace a previous one that was used for the same purpose but which received substantial unfavourable feedback from end users. The main comments were that it was too bland, almost prison like and that the content was not presented in any semantic order. In the two new environments the content and order of information was identical to how the students would experience it in the course materials. The small environment occupied approximately one eighth of the 'virtual land' of the large one and used a smaller number of guidelines.

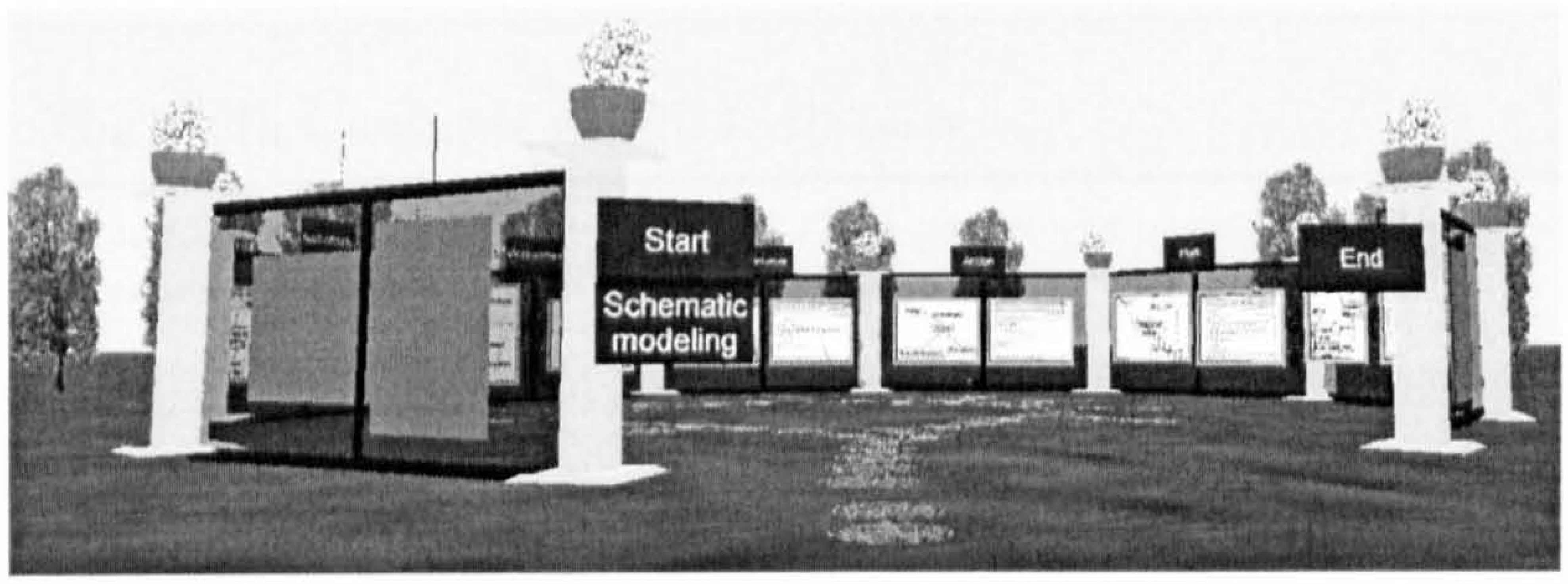


Figure 6-1: The view from the entrance in to the small environment.

Figure 6-2: The view from the gallery entrance into the large exhibition space.

As can be seen in Figure 6-1, the small environment consists of a semi-circular display with a few signs to indicate where the student should start and where he or she should exit, and a simple path leading into the environment and around the exhibits. The smaller environment was developed by researchers at KTH (The Royal Institute of Technology, Sweden). The main aspects are that it includes signs, paths and a space which allows easy viewing of the content.

The large environment was built by the author of this thesis and it contains exactly the same content but uses more of the ENISpace concepts. The larger environment enhances the learning experience by grouping related 'patterns' (i.e. generic modelling situations) together. In addition, the larger environment covers a greater virtual floor space and has two floors. The groundlevel houses the main content and the upper level contains a glass walkway that allows users to gain a view of the exhibition. As a result, the environment makes greater use of space, spatial cues and content in order to enhance the users' navigational experience.

	The Main Concepts within ENISpace
C1	*Directional Signs should be provided. The signs should provide detailed information on general direction as well as specific routes.*
C2	*Informational signs should be provided.*
C4	*The Environment should be matched to the requirements and prior experiences of individual users.*
C5	*The environment should clearly define and articulate spaces allowing for clear mapping between the users conceptual and physical view.*
C6	*The environment should allow for features to emerge through use allowing for a range of tasks and ways to complete tasks .*
C7	*The environment should provide a range of clear and relevant landmarks to aid in orientation.*
C8	*The environment should provide a range of functionally relevant paths that are clear to the user and integrated with other aspects of the environment and user tasks thereby promoting awareness.*

Table 6-1: The list of ENISpace concepts examined in this chapter.

6.2.2.1 Space Syntax and Semantics

This section addresses issues relating to the definition and articulation of the environment and thereby examines concepts C4–C6. Maps are provided in order to reduce the effects of the size and complexity of the environment, to reduce memory load on users, improve survey knowledge and make the size of the space clear on arrival. Moreover, there is a second floor that consists of a glass walkway and allows the participants an overview of the main exhibition space. The maps and the glass walkway allow users to gain an overview of the information without having to be inside it. Both methods allow for a physical and semantic view of the content.

To support emergent (concept C6) opportunities the exhibition is organised along a path that intersects the various content spaces. These content spaces contain the various patterns. Therefore as the user walks through the exhibition the content and other features are revealed and thus provide a number of emergent opportunities.

One of the principle aspects of ENISpace is the examination of the underlying physical and conceptual structure of the spaces. As a result the exhibition contains a number of features to support the definition of important spaces, spaces with different functions and related spaces. Within the exhibition, there is one key pattern that needs to be understood; this pattern is provided on a raised platform and is rotated at a different angle to the surrounding areas. This, combined with the path structure, reinforces the concept of this being an important pattern.

The exhibition contains a variety of spaces, for example, the content areas of the exhibition are clearly differentiated from other more general spaces such as those containing the information points. This is achieved by the positioning of the display boards, the use of floor colour and different objects (e.g. a fire). Moreover, floor colours alert users to areas that are related within the environment. For example, all the pattern spaces are on a grey stone floor, whereas the information boards are on a red stone floor.

Other guidelines were applied to the design of the space. For instance, intermediate spaces were built between the pattern areas and only contained information points and stairs to other parts of the exhibition. These intermediate spaces provide communication areas where users (represented as avatars) can meet away from the exhibition content, thereby avoiding cluttering up pattern spaces or disturbing other users. This is similar to the concept of people meeting outside main rooms or on the stairs in public buildings.

6.2.2.2 Landmarks and Anchor Points


Figure 6-3: The main landmark.

Two separate 'landmarks' are provided, the first one (a monument, see Figure 6-3) allows orientation and is marked on the maps. It is positioned in such a way that it should be clear to most users that it is for orientation only. In addition to its position, its shape, size and form make it clearly separable from other objects. It is also clearly visible upon entry to the world and is visible for a large part of the time while walking round it. As the monument is clearly different from the central area, this will allow for clarity of function and content, i.e. it is obvious that the statue serves as an orientation landmark. In contrast, the second landmark is the central area and is constructed in a way that makes it clear it contains additional content (it is the key pattern) that is relevant to the learner.

In addition to the two basic landmarks several anchor points are placed within the environment including trees and a fire. When combined with the two main landmarks they aid in the navigation process. For example, the fire stands out significantly against the other features; therefore users should be able to use this to gain some additional orientation and location information. Additionally, the route within the environment provides clear indications of the other routes and landmarks it passes by or through.

Although landmarks have been added to the space it is acknowledged that there are problems in defining exactly what constitutes a landmark (for a thorough review see Chapter 2). Age, gender and semantic interpretations all have an effect on what an individual defines as a landmark.

6.2.2.3 Path Structures

Paths provide a way for users to be made aware of the routes and/or to enhance certain experiences such as learning, enjoyment or excitement. The paths provide links between related patterns and different groups of patterns to indicate the end of the exhibition and to highlight the importance of the final group of patterns. As a result, they provide physical and semantic links between the content. In order to support these aims the environment is activity-based; the paths lead the user between different groups as well as between related patterns and allow users to monitor how much of the course they have completed. All paths are clearly marked through the use of colours and forms. In order to help the users in the process of grouping related patterns there is a differentiation in path, for example paths between related patterns consist of a series of stepping stones with focal points, whereas paths between different groups are blue (Figure 6-4).

In order to aid navigation and to reinforce relationships between patterns the user only has to travel short distances within related areas. In addition, a focal point is provided; if the user stands on or near this point he or she can click on the relevant display boards without the need to adjust the avatar position as frequently.

To enhance the feeling of travelling along a path, archways are placed between each section of the exhibition to provide clear within-path markings (Figure 6-6). The markings combined with the signs allow users to be made aware that they are moving between different groups of patterns. As a result, the paths provide a degree of integration with the environment and the underlying content. The aim here is to enhance the flow experience as the users navigate within the space, to enhance awareness of other sections of the exhibition and to provide a way of guiding the user through the space. Therefore, if the users follow the paths they should be able to move around the environment without the need for complex keystrokes and should be able to avoid colliding with objects.

In addition to providing signs, the paths provide a method for users to orientate themselves. A number of methods are employed. On arriving in the exhibition there is a clear initial encounter with the central area attracting the users'

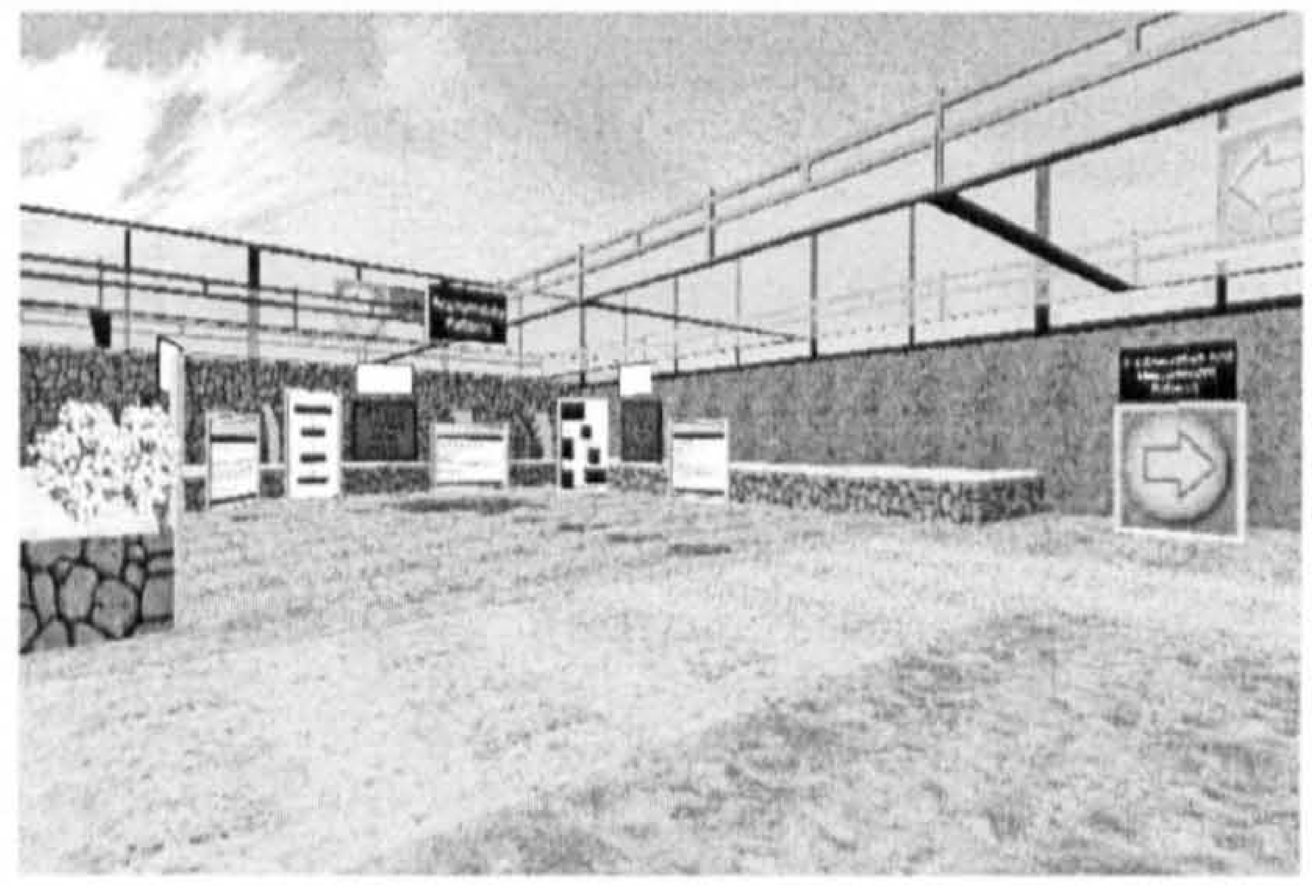


Figure 6-4: A view from the entrance to a group of patterns. Note the main pathway (starting bottom left) and the stepping stones in the centre.

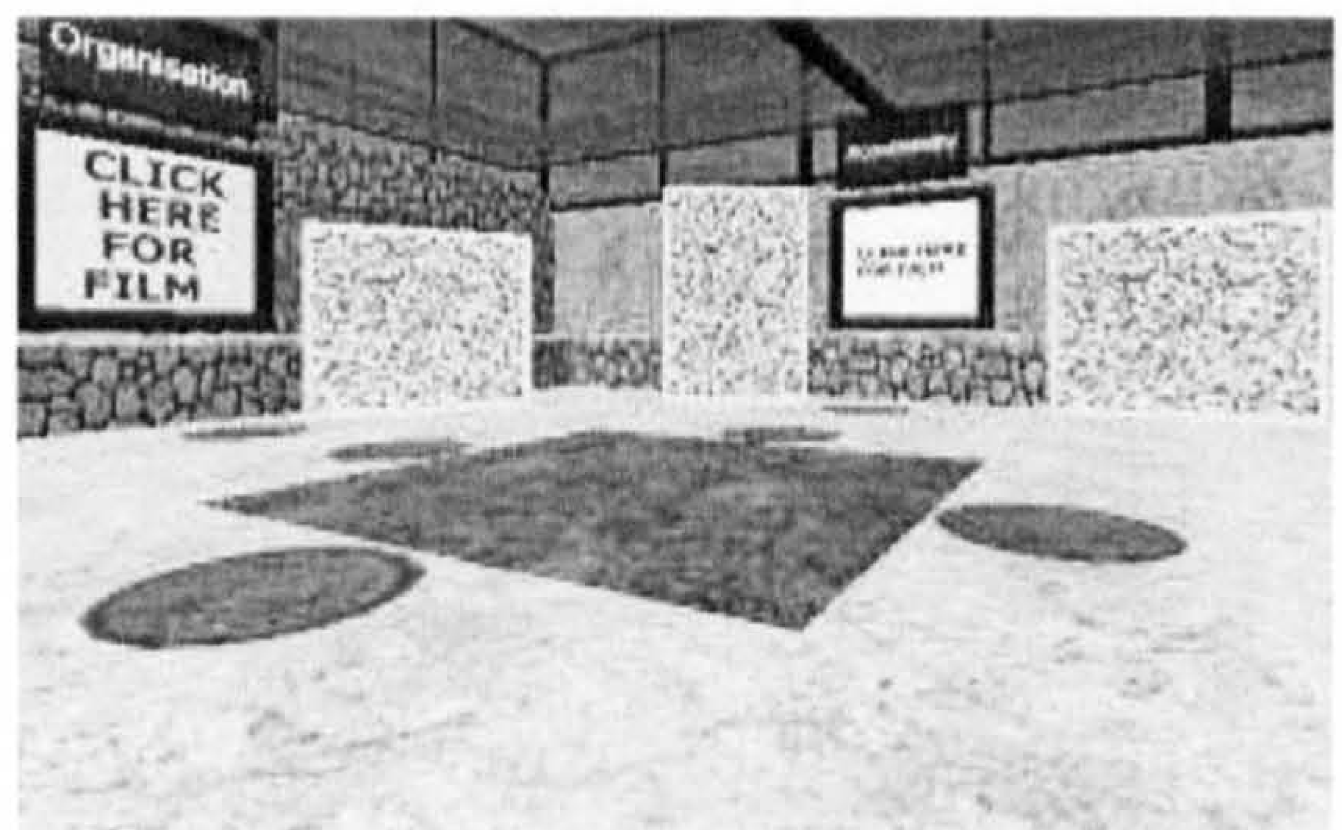


Figure 6-5: A path focal point, this is the large square in the centre, the surrounding stepping-stones represent the path.

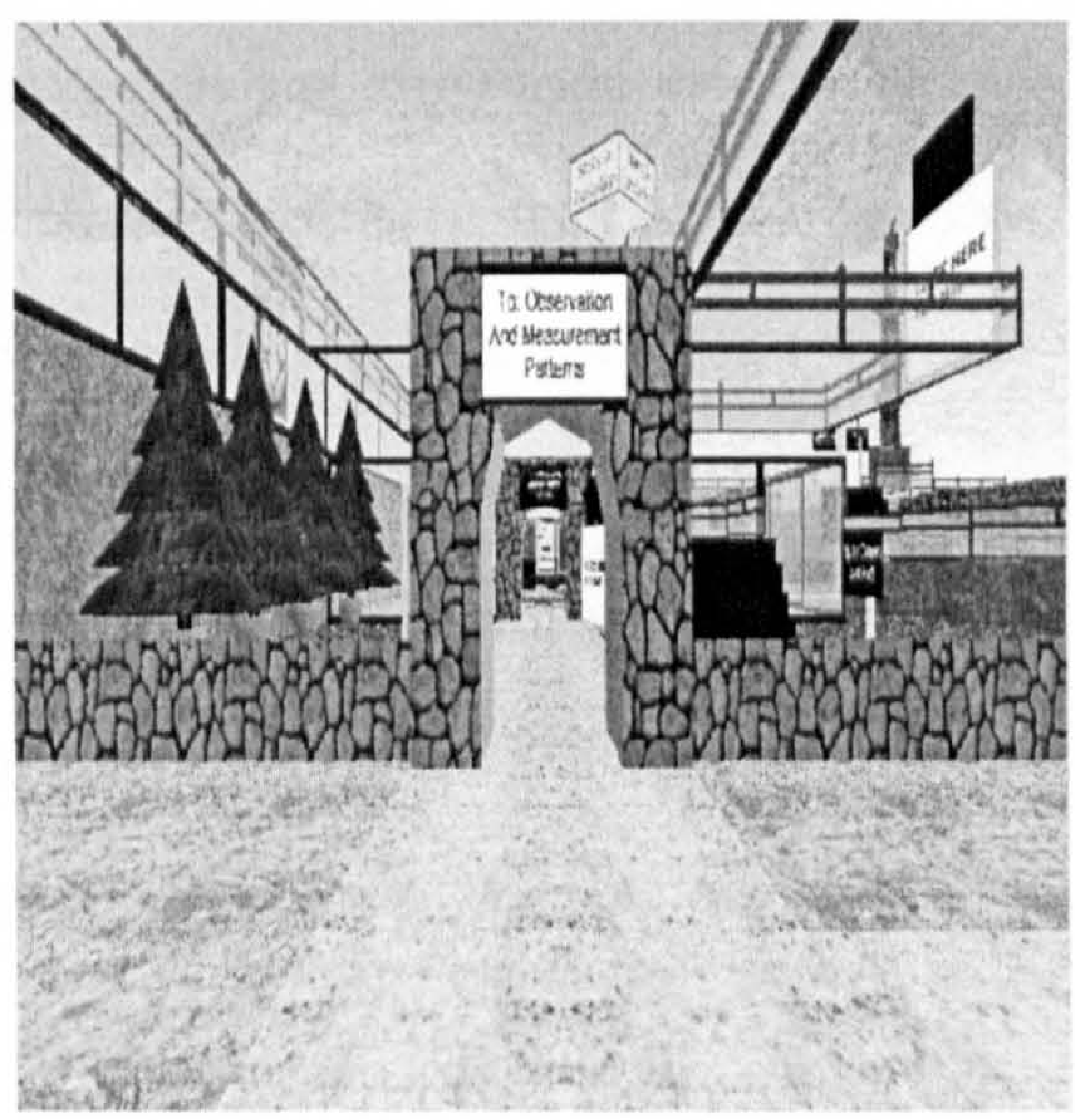


Figure 6-6. A view from one area through an arch-way to the intermediate space and then into the next group of patterns.

attention. If they follow the predefined paths this will be their final destination. Moreover, archways are used between different groups of patterns. The archways combined with the blue paths provide a clear initial encounter and clear approach to new groups of patterns. All rooms make use of the clear approach guideline (see Figure 6-6). For example, on arriving in a new group of patterns the user walks through an archway (see Figure 6-6), the paths on the ground change to stepping-stones, the display boards are positioned differently and other architectural forms are used to enhance the feeling of arrival. The final group of patterns is located centrally, raised and at a different angle. This indicates to the users that they have arrived at the final part of the exhibition.

6.2.2.4 Signs: General Issues

The exhibition contains a number of signs, which are consistently marked (using appropriate colour, language and symbolic metaphors). Signs leading to exits are black on red (see Figure 6-7), directional signs are blue on yellow (see Figure 6-8), information point signs are green (see Figure 6-9) and arrows are used to indicate direction. To improve the visibility of the signs they are placed at locations where they are easily seen. For example, on arrival in the exhibition if the user walks down the stairs, arrows and other signs are immediately visible. Moreover, all the signs are above or to the side of objects within the environment thus making sure they do not reduce the visibility of the environment. In order improve the definition of the space certain signs are only used in specific locations such as the information point signs.

6.2.2.5 Directional Signs

The exhibition content contains five areas (or sectors) and this structure is utilised within the directional signs to provide a clear marking of distance and time to reach a destination. Each area that contains patterns is numbered starting at 1, then clockwise through to 4 and finally 5 for the central space (see Figure 6-10). The use of consecutively numbered areas is consistent with a study by Butler and Aquino (1993) who found that directional signs should make use of consecutively numbered areas. Arrows are utilised throughout the exhibition to provide a clear marking of direction to patterns, stairs and exits.

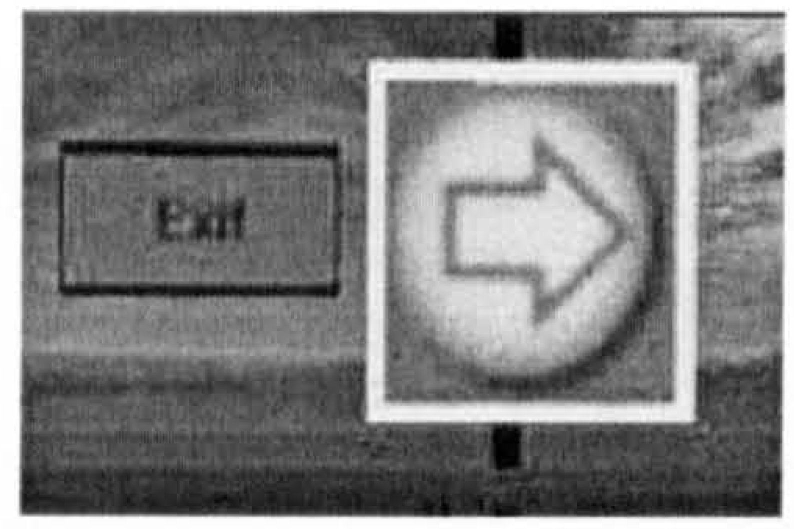


Figure 6-7: (Left) The exit sign and (right) a directional sign.

Within the exhibition the use of directional signs maps onto the pattern groupings and therefore complements the underlying structure of the physical and semantic space. In addition, users are permitted to take alternative routes, this is achieved by the use of signs and paths clearly indicating the directions of other patterns and areas of interest.

Figure 6-8: A directional sign for the stairs.

As users navigate within the exhibition space a number of signs are used to help them monitor the route. These signs allow users to become aware when they initially encounter a new group of patterns, and then as they take the route towards them arrows are used to make the approach clear. In order to allow for clear arrival at a

Figure 6-9: An information point.

destination the patterns are labelled. The exhibition has one main route which is clearly marked using numbered signs and arrows. These design features combined with the blue paths and other features make the main route prominent. This main route is also appropriate for users' tasks because if they follow it they will be able to view the entire content within the exhibition space.

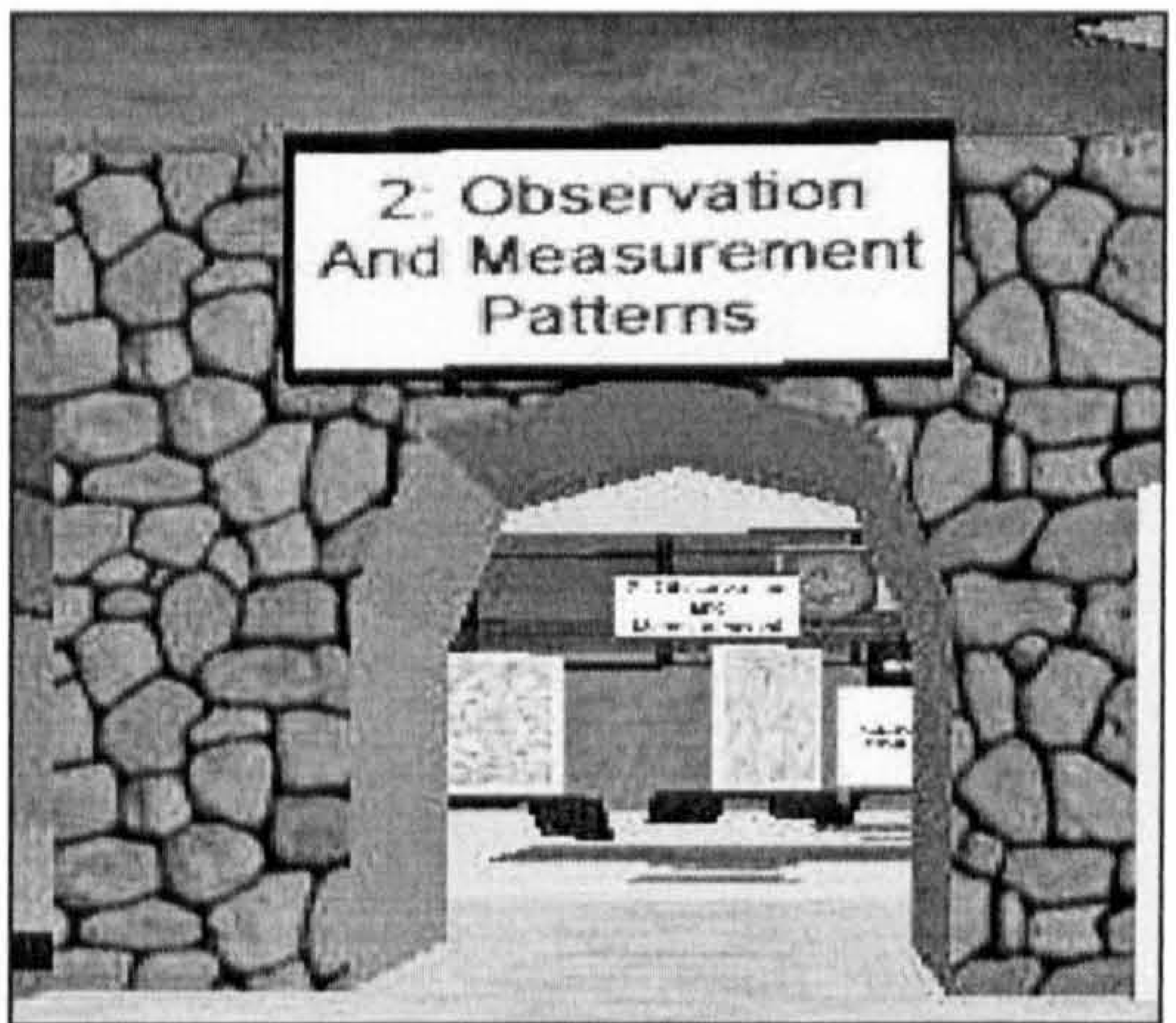


Figure 6-10: An archway and a sign containing the name of the next group of patterns and the number of the area the person is entering.

Moreover, if the users decide to leave the route they will remain orientated within the whole environment. This is achieved by using area numbers (discussed earlier) and gives an indication of the users' current locations as well as the distance from the entrance. In doing so, the environment allows users to exit from a predefined route and remain oriented within the whole space. Finally, there are frequent signs and exits to the glass walkway.

6.2.2.6 Other Signs

Informational signs are provided throughout the environment and are used to uniquely mark objects and locations. In addition, the Active Worlds software that is used to run the exhibition provides information on other users and their actions.

Within the environment there is minimal need to provide warning and reassurance signs as users are not able to undertake actions which may damage data. The only potential action which may divert the users from their tasks is accidentally exiting the exhibition. Therefore clear warning signs are provided to mark the main exit and exit to the gallery, these use black writing on a red background (see Figure 6-7).

6.2.3 Procedure

The participants were asked to complete a range of tasks and were permitted to complete them in any way they chose. This resulted in a situation where the study takes a largely exploratory perspective, where the objective is to uncover what cues are being used rather than forcing people to use specific ones. As a result, this study examines whether knowledge from the navigational behaviour of people and their use of cues in real world environments is applicable to the design of 3D environments. In addition it examines whether interaction patterns vary with the type of navigational activity being undertaken and whether use of cues is dependent upon environmental structure.

The participants were assigned either to the small or large environment. They participants were then asked to find out what they could from the environment on the premise that they would be tested on the content. They were not given any time limits on exploring the environment and could leave it at any point regardless of whether they had viewed all the relevant content. However, they were advised that they should expect the trial to last no longer than one hour. Having completed this first (exploration) stage the participants where then asked to complete the first section of the questionnaire (a description of the content of this is given later). The participants were then asked to return to the environment and complete a wayfinding task. Having completed the wayfinding task they were asked to complete the second stage of the questionnaire. This second stage consisted of them being asked questions relating to the cues they had just made use of during the wayfinding test. In addition, they were also asked to provide responses to a range of questions and finally draw a sketch map of the environment.

In order to assess the relative usefulness of the cues between exploration and wayfinding the evaluators were asked not to use the maps during the second part of the trial. This request was made so that they could not refer to the map and then travel in the desired direction. By doing this, it is possible to uncover the degree of environmental knowledge they had obtained during exploration.

6.2.3.1 Questionnaire data

The questionnaire contained up to 26 propositions (copies of the full questionnaires for both environments can be found in Appendix C and a list is provided in Table 6-2) which covered the use of cues and levels of subjective satisfaction during the exploration and wayfinding phases of the trial. The questionnaire uses a 5 point scale ("Strongly agree" = 1, "No Opinion" =3, "Strongly Disagree"=5) for each proposition. Although they use a uniform scale in all propositions it is not possible to indicate that a response of 1 in relation to one proposition elicits the same feeling of agreement as in relation to another, it is also not possible to argue that the scale is of equal intervals between each choice. As a result, it is assumed the data obtained are based around a ranking rather than raw score. In the final part of the questionnaire, all subjects were asked to answer five questions relating to their general opinions of the environments (see Appendix C). These asked for the aspects they liked or disliked within the environment, which aspects they encountered problems with and finally they were asked to characterise the exhibition using their own terms. The latter has not been analysed within this study as it is the focus of the research at KTH rather than within this thesis.

In the following analysis, ci = confidence interval, p = statistical significance, S1 = total samples from environment 1 and S2 = total samples from environment 2. The S1 and S2 numbers reflect the total number of responses to that proposition less any 'no opinions'. The maximum values for s1 and s2 are 22 and 18 respectively. Similarly, e1 and w1 refers to the total samples for exploration and wayfinding within environment 1 and is calculated in a similar way. Finally, responses which contain no opinion or nothing at all have been removed.

6.2.3.2 Video Analysis

The objective of the video analysis was to ascertain the navigational behaviour within the environment; in particular, how and where the subjects deviated from the provided paths. By undertaking this analysis it is possible to validate concepts C1 (use of directional signs), C6 (features should unfold through use) and C8 (provision of paths). In turn this helps to validate whether these concepts can be used to design 3D environments and whether interaction patterns and subsequent use of cues within environments are dependent upon the type of navigational behaviour. The video analysis was also used to ascertain which cues people were using while navigating, which paths they took, signs they viewed, maps they viewed and from which focal points they viewed information.

The analysis took the form of viewing each participants movement within the environment. Initially the exploration task was viewed, during which time the participants approximate position was transcribed onto a simplified map of the

	The large scale environment list of propositions
1	It is easy to understand how the information is organised within the exhibition.
2	To learn from the exhibition is easy.
3	The exhibition is engaging.
4	The content of the exhibition is comprehensible.
5	The exhibition stimulates thinking.
6	I don't feel tired at all.
7	The exhibition is sterile.
8	The maps helped me find my way around.
9	The maps helped me gain an overview of the exhibition.
10	The floor colours helped me gain an overview of the exhibition.
11	On arriving in the exhibition I was able to comprehend the size of it.
12	The paths made it easy for me to find my way around.
13	The paths reflected where I wanted to go.
14	The signs helped me identify areas of the exhibition.
15	The signs reflected where I wanted to go.
16	The paths made it clear when I was entering or leaving parts of the exhibition.
17	The signs made it clear when I was entering or leaving parts of the exhibition.
18	I felt overwhelmed by the amount of information presented to me.
19	I did not feel lost within the exhibition.
20	*The paths made it easy for me to find my way around.
21	*The signs helped me identify areas of the exhibition.
22	*The paths reflected where I wanted to go.
23	*The signs reflected where I wanted to go.
24	*The paths made it clear when I was entering or leaving parts of the exhibition.
25	*The signs made it clear when I was entering and leaving parts of the exhibition.
26	*I did not feel lost within the exhibition.

Table 6-2: The list of propositions given to the subjects who used the large environment. The "*" denotes the proposition was put to them after the wayfinding task.

1	What did you not like about the exhibition?
2	What did you like about the exhibition?
3	What difficulties did you encounter?
4	What is your opinion of the aesthetics of the exhibition?
5	Characterise the exhibition on your own terms.

Table 6-3: The final five questions which subjects in both environments were given.

environment (see Figure 6-11). In addition, each time he or she left the main exhibition space this was noted as a new trip which was recorded separately. Similarly, the main wayfinding task was recorded separately. The latter allows for an examination of the use of cues between different navigational activities.

Not all the participants in Sweden were video taped. As a result data from 14 subjects was analysed in this part of the experiment. Each video clip (i.e. exploration or wayfinding task) was viewed from beginning to end at least three times. Initially a non-stop record was taken which was not intended to be particularly accurate but instead aimed to provide approximate information on what was viewed, routes taken and any major areas of interest while preserving the overall interaction context of the individual. A second view then took place, again this was on a complete beginning to end basis but involved stopping and starting the video clip where points of interest, or previously unnoticed information was apparent. During this view the map derived from the first phase was modified accordingly. Any subsequent viewing sessions were either on complete basis or to examine problem areas, specific points or areas of substantial deviation from the initial map. In order to ensure consistency in the analytical process tapes that were examined first and a random selection of others were reviewed and analysed.

The example journey map (Figure 6-11) indicates the route taken by Subject 3 during the exploration phase. Table 6-4 provides summary information, first what the expected route would be (these are the sector numbers), the actual route taken and the FOLLOW and ROUTE scores. The journey map (Figure 6-11) provides additional information, for example, "F" indicates that the participant stood on a specific focal point and the tick in the box indicates that the map at that location was viewed.

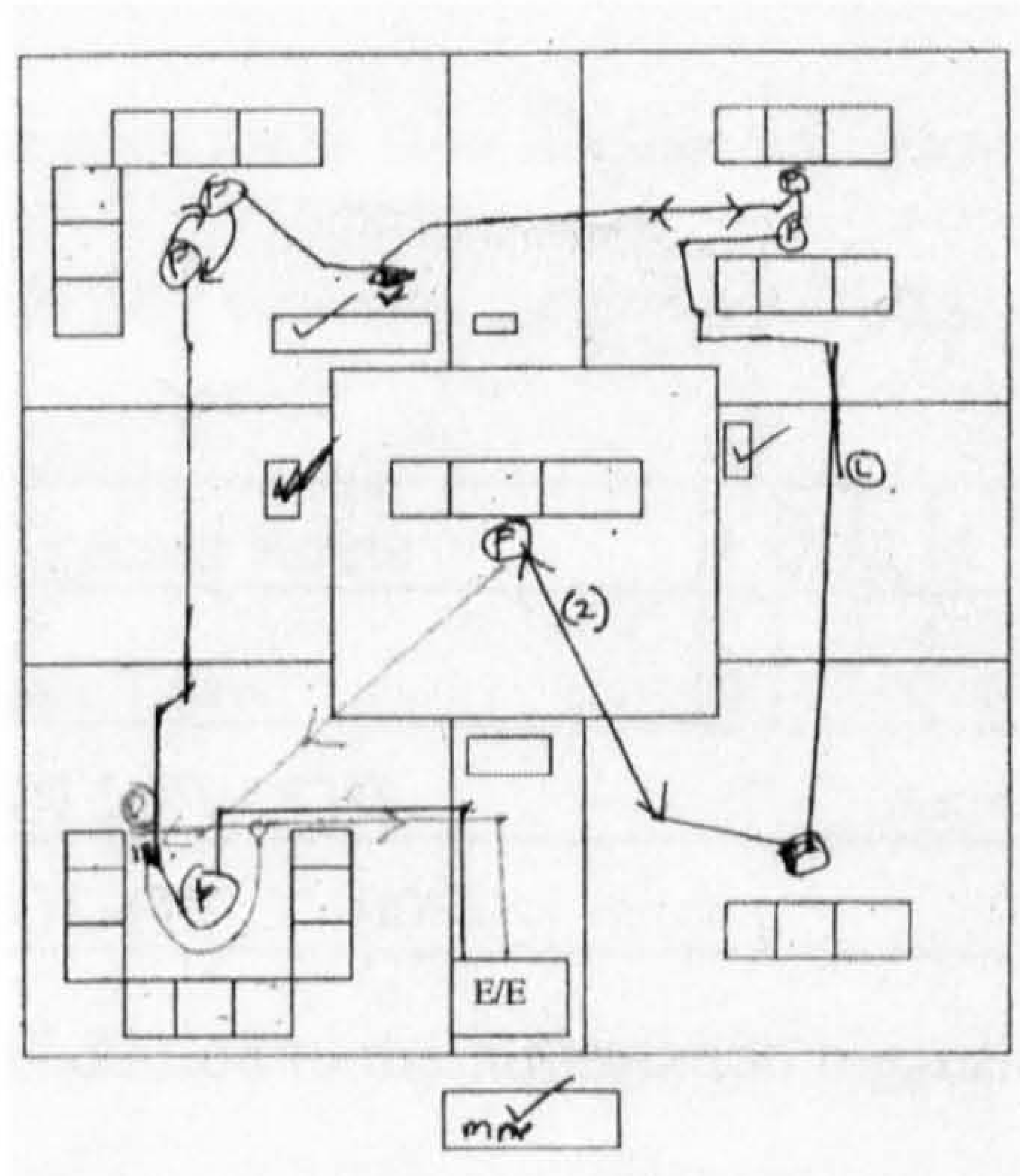


Figure 6-11: A diagram of the route taken by Subject 3 during exploration.

Overview of Journey Map (left)

The map indicates the subject arriving in sector 1, turning left into sector 2, then following the entire route correctly until sector 8 is reached (bottom right). After being in sector 8 the participant visited sector 9 twice (indicated in brackets), then returned to sector 8. Once they were back in sector 9 they then returned to sector 2 then to sector 1 before exiting.

$$\text{FOLLOW} = \frac{\text{Total number of correct journeys between nodes X 100}}{\text{Total number of journeys made within the environment}}$$

In order to ascertain the effectiveness of individual cues and level of route-following behaviour within content areas (nodes) of the exhibition the FOLLOW score was devised. This score allows for an assessment of the willingness of users to make use of cues between individual areas of the exhibition. To calculate the FOLLOW score of the large exhibition, the space was divided into nine areas, which consisted of the main content spaces and the four intermediate spaces. A log was kept of the journeys made by each participant between each content area of the exhibition.

ROUTE = Total maximum percentage of anticipated route followed

A second measure of percentage of route followed was calculated; this was known as the ROUTE score. This ignores the overall efficiency of the journey and instead focuses on to what degree the participant has followed the entire route. For example, a person who takes the exact route between the beginning and end without any deviations would receive a score of 100%. In addition, if a person initially takes a random route then decides to follow the entire pre-designed route from beginning to end they will also receive a ROUTE score of 100%.

Expected Route	1	2	3	4	5	6	7	8	9	8	1			
Route Taken	1	2	3	4	5	6	7	8	9	8	9	2	1	
FOLLOW 83%														
ROUTE 90%														

Table 6-4: The expected route, the actual route taken. Also the FOLLOW and ROUTE scores for subject 3.

In addition to the information regarding participants' movements it is also necessary to examine at which points in the environment people are making certain navigational choices, in particular when they are deviating from the designed routes. Moreover, it is desirable to examine what cues (e.g. signs and maps) are being used in what areas..

6.2.3.3 Sketch Maps

The method of analysis used is based on that contained within a study of navigation within 3D virtual spaces (Billinghurst and Weghorst, 1995). Initially each sketch map was assessed for the various properties it contained, e.g. trees, maps, sectors, paths, stairs, the fire and the monument/landmark. A record was kept of the number of times each item was contained within the sketch maps. The sketch maps were then analysed for accuracy in relation to a subset of the named properties drawn by the participants, for example, the number of correctly named and located sectors. It should be noted however that the assessment was not based on absolute but relative accuracy. For example, how many of the sectors are correctly placed in relation to the entrance stairs drawn by the participant. This method was chosen to overcome the problems associated with people drawing maps which are initially oriented incorrectly but which may be reasonably accurate once the orientation distortion is removed.

The subjects were asked to draw the sketch maps after they had completed the final set of propositions in the questionnaire. In effect, this means they had been exposed to the environment twice and were being asked to draw the map based on their exploration and wayfinding experiences.

The sample sketch map (Figure 6-12) contains a range of the design features. Each sector is correctly named and placed and the key pattern is highlighted in the centre.

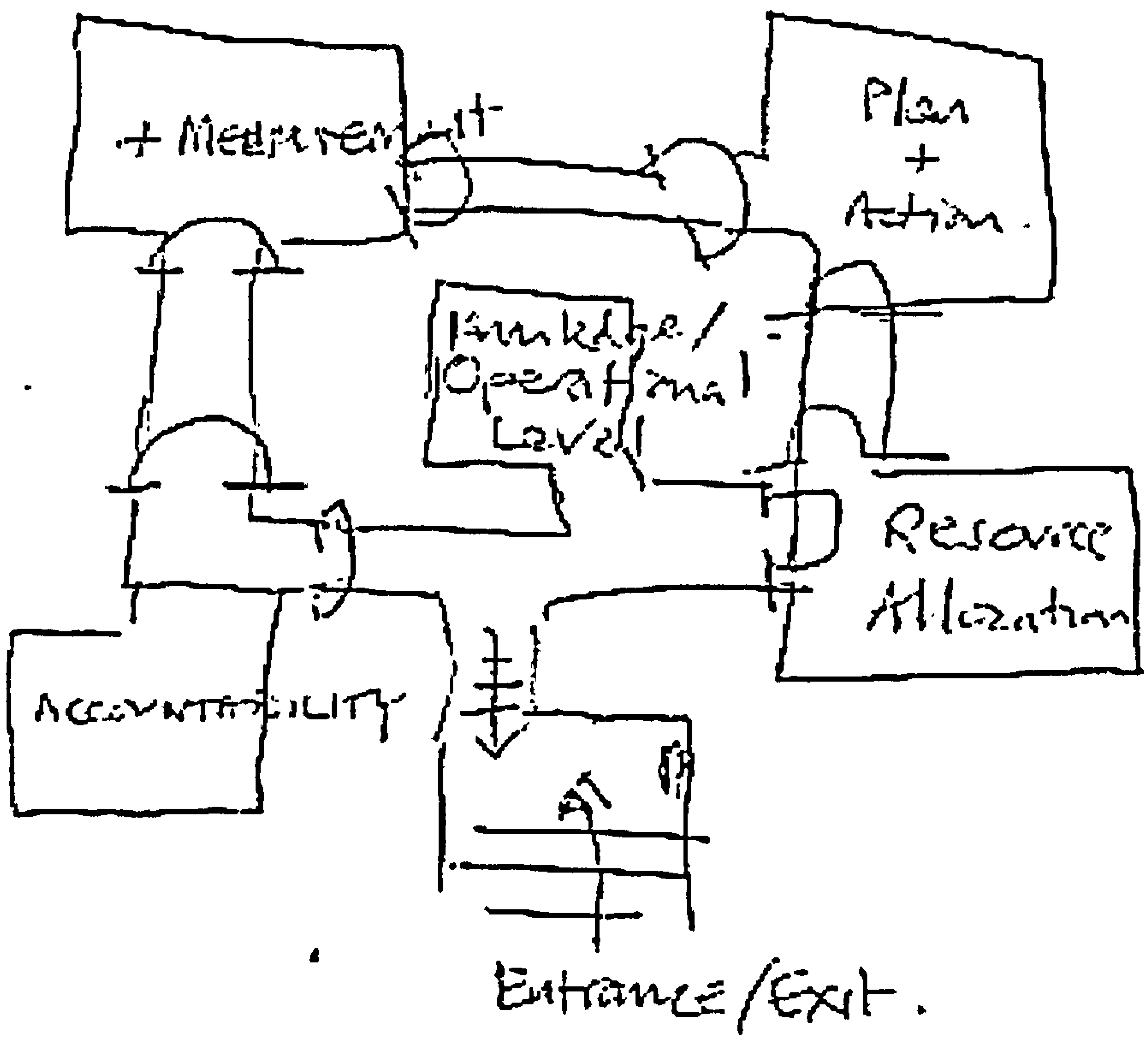


Figure 6-12: The map is deemed to be path and sector based. It contains the following scores archways=8, stairs=2 named sectors=5.

The intermediate spaces between the content areas are marked, although they exist because of the path intersecting the space they occupy. In addition, there are paths provided between each sector with the stairs and archways clearly marked. It is clear from the example sketch map that it contains a range of the design features. The sketch map has a high relative object score for the placing of the sectors. A score of 5 was assigned to this rating due to the fact that all sectors were correctly placed and a score of 2 was assigned to the relative object score for the stairs.

6.2.3.4 Statistics Used

The study uses a range of qualitative and quantitative measures, the aim being to use a combination of results to corroborate any claims made. In addition a range of non-parametric statistics was used on the data obtained from the questionnaires and journey maps. Non-parametric statistics were chosen as the data sets do not typically exhibit properties that are consistent with normal distributions. However in common with normally distributed measures the proposition data will use mode, median and to a lesser degree mean in order to ascertain the level of agreement of subjects using the environment. In order to test for significance two measures were used, the Mann-Whitney U and Wilcoxon signed rank tests were used. A significance level of $p<0.05$ has been selected as indicating the results are not the outcome of random factors. All the statistical calculations were derived from data which was initially stored in MS-Access™, then transferred directly in to MS-Excel™ where upon Analyse-It™ was used to calculate the relevant results.

It should be noted that this thesis will not discuss individual differences in spatial cognition owing to factors such as age and gender, although it is acknowledged that these may have a part to play in interpreting the final data (Thorndyke and Stasz, 1980; Sjolinder, 1998; Waller, 1999). Rather the intention is to provide a broad set of results upon which others may examine these issues at a later date.

6.3 Results

The results are presented in three main parts. Section 6.3.1 focuses on the exploration within the large environment although it also includes some comparisons with the same issues in the small environment. Section 6.3.2 focuses on the change in the use of cues and navigational behaviour between exploration and wayfinding in the large environment. The last section (6.3.3) covers any general findings.

6.3.1 Exploration

6.3.1.1 Signs

The responses to the questionnaire indicated that the users felt signs were beneficial in the large environment. The subjects indicated that the signs helped then identify areas of the exhibition (mode/median=2 s1=21) and reflected where they wanted to go (mode=2 median=2 s1=14). Moreover, they also indicated that signs helped them to notice when they were entering or leaving parts of the exhibition (mode=1 median=2 s1=21).

6.3.1.2 Paths and Routes

The value of the paths and routes within the environment was highlighted by a range of factors such as the responses to the questionnaire, the journey map data and the sketch maps. Responses to the questionnaire data strongly indicates that the use of paths is dependent upon the size and complexity of the environment, this is evident from the data obtained when subjects were asked whether the paths made it easy to find their way around. The subjects responses were statistically significant ($p<0.02$, s1=19 s2=16) indicating that the use of paths for finding their way around was dependent upon the size of the environment. Further to this, it was also found that paths were less useful for helping the subjects find their way around within the small environment ($p<0.02$ s1=15 s2=15).

Main Content of Sketch Map	
Path	11
Numerical	5
Non-path	4

Table 6-5: The type of sketch map drawn.

Relative Object Score

	Unnamed	Stairs	Fire
Median	5	3	1
Total	19	14	1

Table 6-7: The relative accuracy as to where objects were placed.

Object	Median	Drawn	Actual
Maps	2	2	5
Stairs	3	17	6
Sectors	5	20	5
Fire	1.5	2	1
Central Sector	1	9	1
Archway	6.5	4	8
Trees	1	1	1

Table 6-6: The median per sketch map/per person who drew the object. Drawn= total number of instances in all maps. Actual is the actual total number in the environment.

The relevancy of paths is further emphasised within the sketch maps of the large environment with 16 subjects drawing path or movement based maps (Table 6-5). Of these, 11 subjects correctly drew paths, whereas others drew what was classed as path based maps, i.e. drawing sectors each of which contain a number that implies a path of movement. In the case of the latter, five subjects maps were drawn that fell within this category. The stairs were drawn in 17 sketch maps (of which 14 were correctly placed) with a median of 3 being included (See Table 6-7). The main stairs to be included were those at the entrance (exit) and to the central sector. The journey map in table 6-8 also points to the users making substantial use of paths.

6.3.1.3 Definition and Articulation

The subjects were asked to provide a range of responses that covered wider aspects of the environment such as feeling of lostness and understanding the organisation of the exhibition. It may be expected that the increased complexity of environment would increase the level of disorientation. However, the results in response to these aspects were somewhat mixed. For example, there was no substantial difference when the proposition 'It is easy to understand how the information on the exhibition is organised' was put to them between the large and small environments. In response to this proposition, the scores were identical (mode/ median=2 s1=20 s2=16) only the mean varied marginally (mean env1=2.09 env2=2). However in the case of both environments subjects did indicate that they were able to understand how the exhibition was organised.

The subjects indicated that on arrival they were not able to comprehend the size of the space (ci=95% significance $p<0.01$ s1=19 s2=15). This would be expected, as on arrival (prior to viewing the maps or the environment from the glass walkway) it does appear more confusing than the small environment. Even with the decreased comprehensibility of the environment at the outset there appeared to be no substantial impact upon the users' feelings of lostness between the two environments(mode/ median=2 s1=20 s2=15).

The results indicated that the large environment helped people understand the content of the exhibition. Four indicators are used to substantiate this, namely asking if subjects felt they were able to learn easily from the exhibition, whether the content was comprehensible, if they felt overwhelmed by the content and whether the exhibition stimulated thinking. The results from these four aspects indicate that the subjects found understanding the content was easier within the large environment. There was no significant difference for learning, and indeed no significant difference in feeling overwhelmed by the amount of information within the two environments. However, when asked if the content of the exhibition was comprehensible the large environment had significantly improved ratings over the small environment (mean/median env1=2 env2=4) with the result approaching statistical significance ($p<0.07$). The three statistics although mixed in their results do imply that the large environment had no negative effect on learning, however the comprehensibility did improve substantially.

6.3.2 Cue use between Exploration and Wayfinding

The following section examines the relative use of cues between the subjects first entering the exhibition (exploration) and their subsequent wayfinding tasks in the large environment. Table 6-8 provides a listing of the results for the FOLLOW and ROUTE scores for each subject who was videotaped. The subject ID is simply the reference each person was allocated, the ones starting with the numbers are simply the date in Swedish notation and the time the trial commenced.

	Follow		Route	
Subject ID	**Explore**	**Wayfind**	**Explore**	**Wayfind**
990717:1234	77%	0%	50%	0%
2970715:1306	86%	0%	60%	0%
990713:1550	100%	100%	100%	100%
990719:1809	86%	0%	100%	0%
Subject 1	100%		100%	
Subject 8	78%	80%	50%	40%
Subject 7	90%	100%	90%	100%
Subject F	100%	100%	100%	100%
Subject B	100%	0%	100%	0%
Subject D	92%	100%	100%	100%
Subject 9	64%	100%	40%	100%
Subject 3	83%	0%	90%	0%
Subject 6	75%	20%	50%	20%
Subject H	60%	0%	50%	0%
Mean	85%	46%	77%	43%
Median	86%	20%	90%	20%

Table 6-8: The above table provides an indication of route following behaviour (follow) and the total amount of the specific route followed (route) behaviour. The table presents the two scores for both exploration and wayfinding.

One of the main aspects of the study was to examine the relative use of paths, signs and routes during exploration and wayfinding. The results give an indication that there is a transfer of the use of cues and navigational behaviour between real and virtual environments. Moreover, that the use of cues varies between exploration and wayfinding. The initial assumption is that the use of these cues would become less once the user becomes familiar with the environment. In order to validate this assumption a repeated measures test was undertaken. This involved analysing the journeys between areas and the percentages of the total route followed by individual users.

Initial examinations of the questionnaire data did not provide any clear indications that the subjects made less use of signs, paths and routes as their knowledge of the environment improved. Indeed when comparing the use of these cues between exploration and wayfinding there was found to be no statistical significance. However, examination of the journey map data provided contradictory evidence.

The FOLLOW score provides an indication of whether people are following the routes between individual sectors. The results of the FOLLOW score indicate that there is a link between navigational behaviour and the use of cues in real and virtual environments. This is evident from the change in the percentages between exploration and wayfinding. Data from the journeys between individual nodes indicated that the correct route was taken for between 60% and 100% of the total journeys undertaken during the initial exploration phase (mean=85% median=86%). The downward trend of means and medians continues within the data obtained during the wayfinding stage (mean=46% median=20%). As a result, it is possible to conclude that route following behaviour between individual sectors is dependent upon the level of familiarity with the environment. Evidence for this is provided in the ratings for use of individual routes between exploration and wayfinding (ci=95% p=0.02).

The second indicator of route-following behaviour (ROUTE) is the percentage of the total route followed. The results from this score also validate the initial claim that paths-and-route following behaviour is dependent upon the user's familiarity with the environment and their navigational task. Results from the exploration phase indicated that on average users would follow 77% of the specified routes with results ranging from 50–100% (median 90%). This fell during wayfinding (mean=43% median=20%).

The latter statistic indicates that people are willing to follow large parts of a pre-defined route or path (ci=95% p=0.02) more readily during exploration than wayfinding. This indicates that although people are still making use of paths/routes they are becoming more reliant on knowledge they posses of the environment.

The analysis of route following behaviour points to a change in navigational strategy between exploration and wayfinding For example, several subjects would follow 100% of the route during exploration, however during wayfinding this would fall to 0%. In contrast, other subjects would appear to follow routes accurately (100%) during both exploration and wayfinding. Clearly, these behaviours do require closer inspection in any future studies.

Further evidence to support the hypothesis that as familiarity of the environment increases the use of cues and behaviours changes can be found in tables 6-9 to 6-11. Table 6-9 provides a list of the cues used and deviances between different sectors of the environment. For instance between sectors 1 and 2, two subjects deviated from the expected path during the first stage of exploration and 3 deviated from it during wayfinding. In addition, during exploration between sectors 1 and 2, one person viewed a sign (see Table 6-10), the first map was viewed 10 times and the entrance map 14 times (see Table 6-11). Further to this, when the users were wayfinding between sectors 1 and 2, four signs were viewed.

The results in Tables 6-9 to 6-11 provide a clear indication that as the subjects became more familiar with the environment they made fewer navigational errors and relied less on the use of certain cues. This is illustrated in the lower number of deviations from the expected route between exploration and wayfinding (see Table 6-9), although there is an exception to this when moving between sectors 1 and 2. Moreover, users' use of signs fell between exploration and wayfinding (see Table 6-10). As the subjects became more familiar with the environment during exploration they made less use of the maps (see Table 6-11).

While there is no doubt room for improvement in the design and placement of focal points (the central areas contained within each of the content spaces), the study found that the participants had a tendency to stand at or near then.

No statistical analysis was carried out on the signs, map and focal point results as the data are less reliable than the journey map information. However, it does indicate a clear change in behaviour at the start of routes when there is a greater use of signs and maps than later on in the journey. It also indicates changes in the use of signs between exploration and wayfinding that is echoed elsewhere in other results obtained in this study.

	Number of Deviances from the Expected Route									
Sectors	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-8	8-1
Explore	2	3	6	3	5	2	4	1	2	
Wayfind	3	1	0	0	0	0	3	2	0	0

Table 6-9: The total number of deviances between each sector for all subjects.

	Signs Viewed By Subjects During Exploration and Wayfinding									
Sectors	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-8	8-1
Explore	1	9	8		4	1	2	3		
Wayfind	4	4	1		3	0	1	0		

Table 6-10: The number of signs viewed in the intermediate spaces between sectors by all subjects.

	Number of clicks on a map										
Sector	Entrance	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-8	8-1
Explore	14	10		5		2		4			

Table 6-11: The total number of views for each map in the environment.

6.3.3 General Results

6.3.3.1 Definition and Articulation

Views were divided on how engaging the large exhibition was, this was reflected within the raw questionnaire data with the users indicating there was no significant difference between the two environments. In contrast, the large environment was found to be less sterile than the small one (ci=95 $p<0.02$ U-s1=13 s2=15). It might be expected that a large, complex and more time consuming environment would result in subjects feeling more tired after using it. This was not confirmed by the initial results for both environments (mode/median=2 for both environments s1=19 s2=14). However, the substantial change in mean scores between the two environments (env1=1.89 env2=2.53) does indicate there may be some pattern which suggests that on average subjects did feel less tired in the large environment ($p<0.04$).

The information gained from the study of the sketch maps confirms the earlier findings and indicated that several of the design features were retained by individuals in their mental maps of the environment (see Tables 6-5 and 6-6). Subjects indicated that the sectors within the environment were one of the key features within their mental maps, with all 20 subjects drawing maps that consisted of sector-based information. Most subjects correctly identified 5 areas (median 5), and 19 of the subjects correctly laying out 5 of the unnamed sectors correctly (see Table 6-5). Given that a substantial number of the maps contained only sector numbers (only 8 contained named sectors) this would point to the users placing a strong emphasis on using the sector numbers found in the directional signs as opposed to the actual names for the groups of patterns. In addition, the existence of sector numbering within the sketch maps appears to partially validate the dominance of paths within the mental maps of individuals. The importance of the sectors and their orientation is indicated by the fact that nine participants correctly drew the location and orientation of the central group of patterns (see Table 6-6). The results from this part of the study clearly indicate that the use of the areas within the space do help people gain an overview.

The space was further defined through the use of archways and certain other architectural features such archways and trees (see Table 6-6). Interestingly the archways were drawn on a high number of occasions (within individual maps) and correctly in relation to the various sectors within the environment. This would indicate that using additional features to define a space, for example, making entrances and exits clear, also plays a part in improving the environmental knowledge held by individuals. Finally, although they appeared far less frequently, for a number of people the stairs were an important part of their environmental knowledge.

In addition to the physical aspects of the environment that are remembered by the subjects it is important to examine the feelings the users had towards the environment. The final part of the questionnaire provided the subjects with five questions (see Table 6-12) which explored their feelings towards the environment and the features it contained.

The data obtained indicates that the large environment evoked stronger feelings, both positive and negative in comparison to the small environment (Tables 6-12 to 6-15).

This was evidenced by the volume and range of comments, for example, the large environment received a total of 33 negative comments (in respect of 20 separate issues) whereas the small scale environment elicited 16 negative responses (in respect of 16 separate issues). However the small-scale environment received only 11 positive comments (in respect of 9 separate issues), in contrast the large environment received 34 positive comments (in respect of approximately 28 separate issues). Therefore, irrespective of what measure is used, either unique issues or a number of issues, the large environment appeared to stimulate users (both positively and negatively) more strongly. In addition, although the severity or pleasantness of issues was not indicated by users, the large environment had a balance between positive and negative comments, whereas the small-scale environment, had proportionately more negative responses.

The primary negative issues within the large environment were concerned with the cluttering of objects, which was unavoidable due to screen resolution and real estate issues. Interestingly though, the large environment appeared to be considered sterile by six users. This would suggest that a more graphically complex environment but with a more appropriate number of objects would be desirable; this was in part because of technical restrictions in that the version of Active Worlds.

In respect of positive comments a number of the subjects commented on how the environment felt graphically pleasing. They commented that the layout aided their understanding of the content and how it maintained and stimulated interest. Interestingly a number of people commented they enjoyed walking around a large space, that it was easy to navigate within and also that the extra time spent made it feel more like something which you could do at your own pace. This is clearly a desirable feature as it does not make the subject feel pressured into doing a task. In contrast, some people felt that the large environment was strict and efficient and that small features (e.g. paths with small stones) were beneficial. The comments indicate that even if the large environment is not as efficient in terms of task completion time as a website or the small environment, it does clearly show that increased size and complexity can have a positive impact upon people's views and use of a system.

6.3.3.2 Landmarks

Interestingly, no participants included a drawing of the main landmark (monument) within the environment. Similarly, the fire (an anchor point) did not feature substantially in the sketch maps and was drawn by only 2 participants. The lack of landmarks within the sketch maps is not consistent with earlier studies of navigation within the built environment. This may be due in part to the poor visibility of the main landmark and its saliency being compromised due to the poor screen resolution and the obstruction of it by other objects. The complete lack of prominence by the main landmark would suggest either that there were general problems with its legibility or that because it had no semantic relevance users were not making use of it. This is evidenced by the fact that the central pattern played an important part in the sketch maps and in many ways could be interpreted as a landmark. This issue is highlighted within the ENISpace guidelines.

Although there was a lack of landmarks and anchor points, there is a clear indication that the semantic prominence of the final group of patterns (the central area) did provide a form of landmark or anchor point. This is evident from the number of people

Large Environment: Positive Aspects
Graphics.
Good to be able to relate concepts to places.
Keeps interest up. (3)
Relaxes mind from learning with distractions.
Well laid out.
Very easy to walk through different sections. (2)
Wandering around. (2)
Very engaging.
Nice splitting of data/exhibits into genres.
The little extras. (2)
Brief and to the point.
Easy to find way (2).
Take time to do things at own page (like a museum, I like museums).
Informative.
Map.
Paths with stories.
Signs.
Nice to have general overview by map.
Bright, colourful, remains pleasing to the eye,
Liked glass effect.
Graphics use for locating things but tacky.
Fine, more monuments please!
Ok to make your way around.
Generally very good.
Good. (2)
Strict and efficient.
A bit sterile but nice.
Number of issues: 28
Total comments: 34

Table 6-12: A list of positive responses for the large environment. The number in brackets is the number of times that issue was mentioned.

Small Environment: Positive Aspects
Felt like an exhibition.
Background scenery. (2)
Easy to navigate clockwise.
Paths helped navigate.
Natural flow/sequence.
Liked general organisation.
Simple and easy to look around (2)
Good to be able to go round in your own way.
Pleasant interior.
Total Comments: 11
Total Issues: 9

Table 6-13: A list of positive responses for the small environment. The number in brackets is the number of times the issue was mentioned.

Large Environment: Negative Aspects
Too much information at entrance. (2)
Too cluttered/Too many objects. (5)
Signs obstructing other signs.
Layout not clear where exhibition starts and ends.
Glass floor confusing at first glance.
Entrance/exit not linear or clear.
Orientation keeps changing in maps. (2)
The platforms and sectors are daunting.
Not having access to maps all the time.
Not easy to find specific items. (2)
Ugly signs.
Had to walk long way between patterns.
Difficult to get overview at beginning. (2)
Sterile. (6)
Difficult to get interested.
Poor sign posting in accountability patterns
Too bright and colourful textures everywhere.
Many narrow paths with no function.
Glass walkway makes other colours bland.
Feels half finished.
Total Comments: 33
Total Issues: 20

Table 6-14: A list of negative responses for the large environment. The number in brackets is the number of times that issue was mentioned.

Small Environment: Negative Aspects
Too much too quickly.
Obviously describes different parts but in a disjointed way.
Uninteresting visually.
Interesting initially but then it no longer becomes interesting.
Didn't enhance earning.
Lack of overall structure.
Ugly Signs.
Walking along between patterns.
Never ending surroundings confusing.
Feels like there is more which reduces focus on exhibition.
Circle layout felt wrong
Circle layout should be limited in some way.
Paths not immediately obvious.
Initially getting barings, although this is eventually overcome.
Felt like need to see more of exhibition.
Grass.
Total issues and comments 16

Table 6-15: A list of negative responses for the small environment.

who sketched the central area.

6.4 Discussion

The design of the large environment was driven by the idea of improving navigation by enhancing the user experience of path-space relationships. The very concept of path-space relationships focuses the designer into considering the flow or movement as well as the overall experiences in each area of the environment as the user encounters the various patterns, rooms and objects.

The large environment stimulated users (both positively and negatively) to a greater degree than the smaller one, and had an overall positive number of comments. Indeed many people indicated they preferred the aesthetics, paths, areas (districts) and other features. The subjects indicated that these features helped them gain an overview of the content of the exhibition. The range of comments and subsequent results from the questionnaire, journey and sketch maps all indicate that experience and the use of paths helps people during navigation. When paths are combined with other features they increase enjoyment or at the very least stimulate user responses. The experience based approach appears to increase the overall comprehensibility of the exhibition. From the perspective of HCI it would be expected that the increase in complexity of the large environment would result in people feeling more lost, however although the mean scores for the feeling of lostness were higher they were not found to be statistically significant. When this is taken in combination with other indications that users were initially unable to comprehend the size of the large environment, it is clear that the layout, paths, signs and other cues did aid in navigation (and hence reduce the feeling of lostness).

It is clear from the study that within both environments the responses were positive with respect to the use of layout, paths and other features. The only major exceptions being the floor colours and maps. As expected the paths were marked as being less useful within the small environment, however they did not produce an overall negative response from users. In addition, the use of paths, signs and districts (sectors) within the large environment did receive strong positive responses from users and as expected paths and districts (sectors) featured heavily within the hand drawn sketch maps. Further evidence of the use of paths was obtained from video observation and the subsequent journey maps. This is despite the users having a choice at nearly all points during their navigational behaviour as to where to go next.

The study provides evidence that there is a strong link between the navigational behaviour of the individuals and their subsequent use of cues. The questionnaire score data pointed to cues being used less during wayfinding than during exploration. This would point to the users becoming familiar with the environment and therefore not needing to make use of set routes to the same degree as when they first arrive. The pattern of such behaviour is evident within the journey maps which indicates a strong fall in the use of routes as the users move between exploration and wayfinding. The use of cues is also dependent upon the users' navigational behaviour and goals, for example it was observed that earlier on in the navigation process signs and maps were used more frequently. This was more evident when the subjects first entered the environment during the exploration phase. There was a similar drop noted in the use of signs between exploration and wayfinding. This would point to the existence of improving environmental knowledge by the subjects. Although the same behaviour was observed during wayfinding it was also observed that the users were more willing to deviate from the pre-designed routes at the outset. This would indicate the existence of a similar strategy to the wayfinding model proposed by Downs and Stea (1977) for example, on arrival they are initially orienting themselves within the whole space. After orienting themselves within the whole environment, they then chose a route (in this case the predefined one or another one), once on the route they made use of the cues although on average to a lesser degree, thus aiding them in monitoring their positions along the route and recognising they have reached their destinations. From the perspective of the Spence model of navigation, on arrival they can perhaps be seen to browse the space, although to a limited degree by first viewing their surroundings. After viewing the surroundings, they then create (or draw on) an internalised model of the environment in order to perceive the given (gradient) complexity of the task. Having perceived the gradient of the task they then formulate a strategy for its completion which is based around the predefined routes.

The behaviour of the individuals within the exploration and wayfinding tasks points to the existence of mental models of the environment. However, the study indicates that the subjects did not make use of the pre-designed landmarks. Conversely, there is an indication from the high volume of route-based sketch maps and the degree of route-following behaviour that individuals are relying on route-based knowledge to complete their wayfinding tasks. In addition the fact that subjects deviated from the route but were still able to reach the correct destination with few (if any) wrong turns suggests they did hold a clear survey knowledge based model of the environment. In many cases they were able to get the correct initial bearings with relation to the desired pattern and also move directly towards it. The maps also suggest that a grid based structure is inherently useful with respect to aiding in the construction of survey knowledge. In all cases paths (in whatever form indicated) and districts did play a critical role in the design.

6.5 Conclusions

The preceeding study has examined the research questions in this thesis, namely: (1) Whether there is a transfer of design knowledge between real and electronic spaces? (2) Can the concepts be provided in a series of useful guidelines? (3) Are the guidelines useful for evaluation and design of electronic spaces? The study has focussed primarily on the transfer of design knowledge from real to electronic spaces through the provision of a set of concepts and guidelines.

The study provides evidence that the design features were beneficial primarily in the large environment, although they were also beneficial to a lesser degree within the small one. This points to the existence of a size dimension in the use of such cues but given the increased complexity of the large environment subjects did not feel significantly more lost. This in turn provides evidence that the cues within the large environment did aid in navigation and improve the comprehensibility of the content of the exhibition. The study points to the development of environmental knowledge and also clearly indicates that different navigational strategies do exist within virtual environments and that they are broadly consistent with those of the exploration and wayfinding (Downs and Stea 1977). In respect of this, the results indicate that there is a pattern of use which emerges in relation to the use of cues within an environment which is broadly consistent with those found in the built environment, namely that the use of cues is inversely proportional to the level of familiarity (or knowledge) the user has of the environment.

Although the study points to the a relationship between navigational behaviour and the use of cues, there is a need for a better understanding of how they effect one another. In addition, the study provides evidence that understanding the relationships between users, their movement within spaces and the underlying nature of the spaces provides a valid method of designing 3D user interfaces. Also, as part of this study it is important to understand the navigational goals and experiences the user will have within the space. This is evidenced from the fact that despite increased complexity within the large environment users did not feel significantly more lost, were on balance more positive towards it and found the content more comprehensible. Therefore, although there is a need for further refinement of ENISpace it is clear that a combination of the underlying cognitive navigational models and more high level issues related to experience of spaces does provide an effective means of user interface design.

The preceeding study and results indicate that knowledge from the navigational behaviour of people and their use of cues in real world environments is applicable to the design and of 3D environments. The study points to the importance of considering semantics when designing and placing landmarks, evidence of the benefits of directional and information signs (C1 and C2). In addition it provides an indication of the relevance of examining the physical and conceptual aspects of space (C5), emergence of content and range of tasks and ways to complete them (C6) and clear paths (C8). The study also provides an indication that the types of behaviour (e.g. wayfinding or exploration) will effect the cues used.

Chapter 7

Conclusions

This chapter presents a summary of the work contained within this thesis, implications, future directions and conclusions.

7.1 Summary

This thesis started by highlighting the fact that people experience problems when navigating within electronic environments and that current usability practice does not adequately cover the navigational perspective. As a result it specifically explores the concept of navigation within information spaces from the perspective of three research questions:

1. Is there a transfer of design knowledge between real and virtual spaces?

2. Can concepts be provided in a series of useful guidelines?

3. Are the guidelines useful for the design and evaluation of electronic spaces?

In order to explore research question 1, the thesis adopts the navigation in information space paradigm. This paradigm places at its centre the view that people navigate (or interact) *within a space* rather than viewing them as passive observers. In order to examine this concept, Chapter 2 explored aspects of the built environment that effect navigational behaviour including: physical properties (e.g. paths, signs and landmarks), meaning, users personal traits, goals and desired activities. The chapter also explored high-level concepts such as existential spaces (Norberg-Schultz, 1971), the work of Lynch (1960) and Bentley et al. (1985).

The examination of the built environment led to one question, namely how relevant are the design concepts and theories for electronic environments? This question is central to research question 3. In order to address this question a literature review exploring the design and evaluation of electronic environments was carried out (see Chapter 3).

A pilot study into the use of navigational concepts during evaluation was carried out and detailed in Chapter 4. The study used the Navigational Instrument (devised primarily by Prof David Benyon) to evaluate a collaborative Internet application and found that the underlying concepts contained within ENISpace were relevant to user interface evaluation and that it was uncovering issues that were not found using other methods.

In order to explore all the research questions more thoroughly ENISpace was devised (see Chapter 4). ENISpace is a set of guidelines based on the literature review and was implemented in paper and software form. The software version contains a range of supporting features such as documentation and a report generator.

The evaluation study in Chapter 5 found that ENISpace was identifying a range of navigational issues and that the guidelines were presented in a useful way but that there was room for improvement. Despite this the guidelines did prove to be a useful method of evaluation, therefore at least partially answering research question 3.

The 3D environments study in Chapter 6 found that people exhibited a range of behaviours that were consistent with the navigational concepts contained within ENISpace. Examples include the use of paths and signs, and a variation in the use of cues as the users became more familiar with the environment. As a result this study found that there was a transfer of knowledge between real and virtual spaces (1) and that the guidelines were useful in the design of electronic spaces (2).

7.2 Implications of this Thesis

The development of ENISpace and the studies undertaken in Chapters 4 through 6 have a range of implications for the field of usability, in particular:

- *A validation of the navigation in information space perspective as being relevant to user interface design and evaluation.* The studies range from those using ENISpace as a method of evaluation (Chapter 5) to using it to design 3D virtual environments (Chapter 6). The Glasgow Directory Study in chapter 5 found that a range of usability problems were being found. The study in Chapter 6 found that the concepts and guidelines provided a useful method of designing 3D virtual environments.

- *An understanding that the navigational behaviours of individuals within electronic spaces is comparable to that within real world spaces.* The results of the studies (in particular the 3D environments study) provide evidence that users are exhibiting a range of behaviours that are broadly consistent with the concepts of exploration and wayfinding. While it is clear that browsing was taking place in both studies and that users were beginning to develop survey knowledge of the environment in the 3D environments study (Chapter 6), it has not been possible to validate the Spence framework (Spence, 1999). The study in Chapter 6 also indicated that the use of cues varied as people became more familiar with the environment. Examples include the use of maps as people travelled through the space and less use of certain design cues between exploration and wayfinding. This points to similarities in user behaviours and strategies in real and electronic spaces. As a result, it is possible to draw a conclusion that navigation in electronic spaces is comparable with, but not necessarily identical to, actions within the real world. That is, it cannot be argued that it is *exactly* the same cognitive process rather that the observable behaviours are similar. Therefore, given the results of the evaluation and design studies it is possible to argue that there is a need to place greater emphasise upon navigation when designing electronic spaces.

- *The development high-level design guidance, which is applicable across a range of domains.* The studies indicate that the high-level design guidance was applicable across a broad range of domains including: virtual environments, collaborative Internet applications, tourist information systems (including the database, help and 3D components) and educational environments. Evidence for this is provided in the Co-Nexus study in Chapter 4, which explored the early high -level concepts. Further to this, ENISpace was used in the evaluation of a 2D/3D tourist information system in Chapter 5 where the evaluators indicated the relevancy of considering the relationships between spaces, the use of paths and the implementation of signs. Further to this the study Chapter 6 indicated the benefit of considering navigational cues when designing a 3D educational environment.

- *The validity of the overall concepts contained within the guidelines in relation to the evaluation of 2D and 3D environments.* The guidelines have been used to evaluate Co-Nexus (2D) and the Glasgow Directory (2D and 3D) environments. The results from these studies indicate that several of the overall concepts are relevant to the detection of usability problems, and that in many cases the problems would not have been identified through the use of other methods. Typical examples include evaluators highlighting the need to use signs, paths and the use of inconsistency and spatial organisation to enhance the navigational experience. In contrast, where such features are missing (e.g. no signs existed within the Glasgow Directory 3D space) usability problems will be encountered. The studies have also illustrated the need to understand not only the structuring of components within spaces but also their relationships through spatial proximity and path structures. The latter being highlighted within the Glasgow Directory study in relation to movements between different functions (or areas).

- *The validity of the overall concepts for the design of 3D virtual environments.* The guidelines (and concepts) were used to design two 3D virtual environments, the main objective being to explore the use of the cues in the larger of the two environments. The study in Chapter 6 illustrates that the provision of specific design cues can improve what would be traditionally thought of as an overly complex environment. The only area where there were problems in the 3D environments study (Chapter 6) related to the design and placement of landmarks. The study also found that the inclusion of cues did aid in the navigational process to the extent that there was no increase in the overall levels of disorientation within the environment, these results give a strong indication that the design guidance ranging from signs to spatial layout and paths were beneficial to the interaction process. The study also indicates that there is a need to understand the relationships between the various design features rather than considering them in isolation.

- *The provision of design guidance through a software tool* which provides a range of features to make the guidelines easier to use, such as, limited linking between related guidelines, a report generator, and the ability to store comments.

7.3 Related Work

A range of methods already exist that touch upon navigational issues, such as the Kaur guidelines (Kaur, 1998) that provide an indication of the need for basic navigational cues within 3D virtual environments. However, the Kaur guidelines stop short of providing significant information on the use of navigational cues within 3D virtual environments and focus on wider areas of user interaction. Similarly the COVEN guidelines (COVEN, 1997) ignore many aspects of navigation, however COVEN does provide guidelines that explore specific parts of the interaction cycle and to some extent navigation. VRUSE (Kalawsky, 1999) is another set of guidelines that are specific to 3D virtual environments however it does not provide any in-depth analysis of navigational issues. Other researchers such as Ingram et al. (1996b) and Charitos (1998) developed informal guidelines for the design of 3D virtual environments. These researchers built on concepts from architectural spaces from authors such as Lynch and Norberg-Schultz. However, the Charitos design guidance stops short of considering the links between various properties, how these will affect the different navigational strategies adopted by users, and the use of cues by individuals.

Another study indicated the need to adopt ideas from real spaces and apply them to electronic environments (Murray et al., 2000) but stopped short of providing any meaningful guidance. Moreover the work by Murray and many of the other authors discussed have examined abstract situations where the environment had no real purpose.

Existing usability methods such as Cognitive Walkthrough, GOMS and Heuristic evaluation ignore many aspects of navigation and are usually only applicable to 2D environments. Further to this, none of the methods discussed explore how navigational behaviour will be influenced by the use of cues, navigational models or behaviours.

In summary, this thesis builds upon work undertaken by others and has (1) pursued an approach driven by the need to support designers and evaluators in their quest for appropriate knowledge about navigation, (2) developed guidelines which are not tied to any one model or framework (3), has discussed and developed guidelines which can be applied to the design and evaluation of 2D and 3D electronic spaces. As a result, the work differs from previous work as the evaluations were carried out on environments built by others and examined by independent evaluators. An environment was built using some of the ENISpace concepts by a third party and the environments constructed and evaluated have ranged from 2D Internet applications to 3D virtual environments. In contrast many of the previous studies used environments built by those exploring the theories, they have not been evaluated by independent evaluators and have focussed entirely on 3D spaces.

7.4 Future Directions

There is a large amount of discussion on the relevancy of considering navigation in the context of electronic environments and whether it is a metaphor, perspective or paradigm. Therefore in order to explore these issues and aspects of this thesis there are a range of areas for future work including:

- *The need to develop a closer link between navigational models, environmental knowledge and cues.* The studies have indicated a link between use of certain cues and the type of user navigation, however there needs to be a larger study conducted to examine this in more detail. This is particularly the case within 2D environments where evidence that the navigational perspective is appropriate has been provided. However, this thesis has not focussed on which aspects of navigation and use of cues may be appropriate. It is also acknowledged that there should also be a greater examination of the Spence navigational framework and how this influences the use of cues.

- *An examination of the relevancy of landmarks.* There is a need to explore the relevancy of landmarks in interface design and evaluation. The results of the Glasgow Directory study in Chapter 5 indicated that the evaluators thought landmarks were relevant. However, the subjects in the Chapter 6 3D environments study almost totally failed to use the landmarks and anchor points. The main exception being a landmark based on semantic relevance (i.e. the central area of the exhibition space). This indicates that there needs to be a study on the effect that semantics and functionality have on the use of landmarks in electronic spaces.

- *A detailed re-working of the guidelines.* While the studies point to the benefits of using navigational concepts during the design and evaluation of electronic spaces there is a need to improve the guidelines. Areas for improvement could be to provide a smaller number of higher-level guidelines, or to provide guidelines that are contextually focussed i.e. they are specific to individual types of environment.

- *An examination of social navigation and other tools.* There needs to be a closer examination of areas from social navigation. Relevant areas include: the use of foot prints on webpages, recommender systems, using agents to guide people, intelligent, and collaborative systems.

- *Areas of art and design and fun.* While the theories discussed and subsequent guidelines provide some indication as to the importance of graphical design and fun they do not fully examine these areas in any detail. Therefore, there is a need to further examine the influence of aesthetics and user enjoyment upon the navigational strategies adopted by users.

- *Improvements to the software tool.* The current software tool requires a number of improvements including: allowing people to draw their interaction within an interface then assigning guidelines to relevant points within the cycle and a wizard style interface which guides people through the evaluation and automatically displays the relevant guidelines. There needs to be a substantial improvement in the range, quality and flexibility of the reporting options contained within the software. Other aspects include providing better links between the guidelines and more thorough supporting documentation.

7.5 Conclusions

In conclusion, this thesis has demonstrated that there is a transfer of knowledge between the design and evaluation of real and virtual spaces (1). It has illustrated that such knowledge can be provided in a series of useful guidelines (2) and that the guidelines are useful for the design and evaluation of electronic spaces (3). Therefore it has examined three research questions and has uncovered a range of aspects related to the design and evaluation of electronic spaces.

This thesis has presented a view of navigation within 2D end 3D electronic spaces and incorporated a largely theoretical approach into the range of guidelines that provide a methodology for the design and evaluation of electronic spaces. The thesis draws on a range of areas from models of navigation and environmental knowledge to more abstract aspects of environmental psychology and the use of cues and features within real world and electronic spaces.

The thesis has built upon the work of others in relation to evaluation and design methods, existing usability practice, urban planning, environmental psychology and architecture. In doing so it has examined the notion of navigating within information spaces from two perspectives, first as a series of high level concepts and secondly as set of specific guidelines. At this stage it is acknowledged that there are a number of limitations and that there is still some work to be carried out. However, it does represent a comprehensive, validated (in terms of evaluation and design) and theoretically sound approach which is partially usable in its present form but which is definitely suitable for enhancement by others.

This thesis provides a substantial step forward in exploring the underlying concept of navigation in information spaces and its applicability to user interface design and evaluation. It has clearly shown that there is a link between behaviour in real and virtual spaces and that considering only cognitive aspects may not provide the necessary foundation upon which to design and evaluate information spaces. Further to this, as information spaces become more complex, collaborative and diverse this thesis has explored the meaning, behaviour and subjective satisfaction that users experience through issues such as path-space relationships, mutual exclusion and the provision of private spaces. In essence, it has specifically explored the physical view of the space (definition) and the articulation of space (meaning) by examining a range of cues that impact upon such aspects.

As indicated throughout the thesis one of the principal aims was to allow designers and evaluators to focus on navigational issues, in essence to provide them with 'a lens' through which to view such issues. In this thesis the lens is the set of guidelines (ENISpace) that exist in paper and software form. While work remains to be done on the guidelines and software it is clear from the studies that the current methodology does provide a substantial step in the right direction and they are suitable for further development.

MISSING PAGES ARE UNAVAILABLE

Appendix B

The Glasgow Directory Study

The following appendix contains the working notes and summaries from the Glasgow Directory study. It contains two sets of sample comments from evaluators summary reports and the 29 most commonly identified issues as found within the summary reports. Please note that the comments are summaries of those made by the evaluators and were intended for internal use. As a result they do contain grammatical errors, are in abbreviated form and certain other omissions.

Summary Report

Orientation
- Difficulty in keeping track of exact position.
- Difficulty with direction of movement.

Use of Colour
- Colour not used to highlight important objects.

Consistency
- Balloons are not consistent in size or proportion.

Clear Arrival and Approach
- Lots of functions stop short of what is expected and the user must perform another function to complete their task.

Uniquely Mark objects and Locations
- Landmarks should be highlighted.
- Street names should be provided.

Clearly Visible
- Landmarks not always identifiable.

Clear marking of direction
- Direction not clear.

Variety
- Landmarks should be available via category and date search.

Clear Mapping
- User expects street finder and landmark selection to actually locate landmark.

Summary Report

Map Space
- Possible to misinterpret red circles as major landmarks not regions.
- No indication of North.
- Red circles may be misinterpreted as showing only landmarks in that region.
- May be better to use ordinance survey type map..

Database Search
- When user clicks on QuickLink option they are taken to region not landmark.
- Database search hides previous information space, cannot get back to previous state.

Information Display Space
- No way to navigate backwards.
- QTVR- interesting but signs provide wrong information.

Category Search Space
- User may try to take an invalid route using tourism plus date search.
- User must memorise help route information.
- User can select headings which do nothing.
- Map icon takes user to region.
- No orientation information provided with map icon.

General Information Space
- Some options obscure VRML, others do not provide method of going back.

Street Finder (SF)
- Addresses may be misinterpreted as directional signs.
- SF hides list of buildings from view.
- SF does not imply list of buildings.
- SF presents web links not street of building name.
- SF does not find streets but buildings (confusing)

Virtual Model Space
- VRML viewpoints are good.
- Viewpoint navigation may not map to users real life movement.
- Red arrows give no indication of direction.
- Not clear with viewpoint which building it refers to if there is a string of buildings.
- No indication that tourism options may be selected in VRML but not category search (inconsistent).
- Same colours for date and tourism – no visual distinction.
- Merging colours cause problems.
- Ten on informational signs too small.
- When selecting sphere into is displayed (this is good).
- Helicopter fly-by route not highlighted.

List of common issues highlighted by evaluators in the raw reports

The numbers in brackets e.g. (3) indicate the number of times that problem was highlighted within the evaluators raw reports.

1. No (little) indication of what changes after clicking on link
Signs
Use of color metaphors
Links in category search use no colour metaphor [to indicate destination or purpose].
Clear marking of route
User may think that clicking on a link in QTVR world will take them to QVTR model instead it takes them to VRML world. User must then use viewpoint node or similar to get to the right building. This means route is unclear.
Conceptual and Physical Structure
Clearly Marked Paths
Paths between spaces not clearly marked.
Differentiation in paths
No clear paths between information spaces.

Common abbreviations

Dbase = the database search option.

VRML = the 3D VRML model of Glasgow.

SF = street finder.

2. No back option
Signs
Consistency:
Problems finding way back.
Easy orientation within whole environment
Sometimes diffcult to move back to the original space – problem is lack of screen real estate.
Mark optimal routes
No screen navigation provided in QTVR movies thus users cannot get back easily to previous state. User is not aware that right mouse button allows navigation. User may have to remember previous route.
New options or information
When new information is presented to use via general or dbase views, VRML view obscured with no obvious way of getting back.
Conceptual
Define spaces with different functions or requirements:
No way to go back easily once database search results obtained.
Variety:
information space display varies. No way to go back to previous screen (2).
Should relate to user experiences
No way to go back to previous building information window (unlike web browsers).
No back facility.
Clearly Marked Paths
Impossible to go back in detailed view. Impossible to go back after QVTR.
Clear approach
Dbase results: no route back to previous state.

3. Spaces often share same area which is confusing/several spaces are hidden
Signs
Visibility of Signs
Informational (spaces) signs not always visible, done to minimise memory load hence not a bad point.
Visibility of environment
General infomation buttons bring up directional and info signs.
Conceptual
Define Important Spaces
Problem with screen components changing function. Not serious
Define Spaces with Different Functions or Requirements
Not clear when area of screen has changed function. Confusion due to shared screen space with general, vrml, postcards and detailed information/help.
Variety
Varation in displays is confusing (e.g. VRML view changes to general space and vice versa).
Appropriate mapping of physical to conceptual stucture
Dbase search obscures detailed information screen
Clearly Visible
Three hidden spaces at one time, may confuse users

4. No warning or re-assurance signs
Signs
Positive Feedback
VRML: if user selects inapplicable option no feedback is given, they may then re-click the option before working out what is going on. Clear marking of distance/time to reach destination: No clear feedback.
Use of language metaphors
Warning and reassurance signs: no building highlighted in category search. Warning and reassurance signs: category search: if already in region when user clicks on it they don't know reassurance is provided.
Conceptual
Clear within path markings
VRML: when another region is selected no feedback is given.
Clear initial encounter
Building selector: no signs tare provided that alert the user to the fact that they have finished, screen simply updates as criteria is changed.

5. Too much information may cause overload
Conceptual
Emergent opportunities
Interface can quickly show too much intormation, causing mememory overload. (2).

6. Problems keeping track of exact position (orientation)
Signs
Clear location information
No spaces except Street Finder are clear about location.
Conceptual
Appropriate mapping of physical to conceptual stucture
Static pictures provide some assistance but do not map to the conceptual model, making it difficult to orientate oneself.
Clearly separate from other objects
Not enough seperation of orientation only landmarks.

7. Colour not used to highlight important objects
Signs
Visibility of environment
It is sometimes difficult to tell the difference between a sign and a landmark.
Clear approach
Buildings all look the same.
Clear Transition
No routes or clear transitions in VRML model due to similarity in buildings.
Uniquely Mark Object
None are uniquely marked (3). Not all are well marked (3). Street Finder: difficulty in distinguishing interactive and non-interactive objects. VRML: buildings are not highlighted in anyway (3).
Conceptual
Define spaces with different functions or requirements
The environment does not differentiate between different sites and functions. Information spaces in map all use red dots and in the Street Finder different colours or textures would help.
Clearly Visible
Visible but not always idetifiable. Landmarks in 2D spaces well defined but not in the 3D spaces.
Clearly separate from other objects
Problems distinguishing landmarks (3). It is not obvious that people have arrived at objects/locations in VRML view. Ariel map does not make it easy to distinguish objects, but this is probably not neccesary.
Emphasise key landmarks
Problems separating landmarks rest of environment (3).
Some landmarks in 3D model not defined in VRML.
Landmarks and Route Awareness
Landmarks not clear (3).

8. Lots of functions stop short of what is expected (clear mapping)
Signs
Use of symbolic metaphors
The category search uses an inon based map which implies users will be taken to the building in VRML view, but this does not happen.
Use of language metaphors
Warning and reassurance signs: When selecting the map icon, users are taken to region not building.
Clear maring of direction
Street Finder implies finding of streets only but also refers to buildings.
Clear approach
Help option for dbase search displays information for dbase search but not how to get to the dbase search screen.
Clear Arrival
In the Street Finder the user arrives in portion of map, no position is given. Signs provide no information on arrival. The Street Finder does not indicate if search is found or not found. If user wants to arrive at a specific street (VRML) they may have to browse the entire world.
Conceptual
Minimise cost of update
Not possible to look at general areas within the street finder.
Define Spaces with different funcitons or requirements
Street finder appears to have more functions than it has.
Clearly define spaces with related functions.
VRML: some options on the menu link to VRML others do nothing User may think the VRML view may also update street finder and category search but this is not the case.
Mutual Exclusion
Clicking on photograph does not update VRML view.
Should relate to user experiences
VRML: user expects to be able to click on any street and be able to go there.
Clearly separate from other objects
VRML: user may follow a path to a building expecting to be able to get more information on it, but this is not available.

9. Lack of Location Information
Signs
Visibility of Signs
Disappearing signs in HTML. Informational (spaces) signs not always visible, done to minimise memory load hence not a bad point.
Consistency
Information and directional signs not seperable.
Clear Location Information
Hotspots of interest only give info when mouse is over them(2). Red dots give street name in map but not in model, this is confusing.
Conceptual
Define Important Spaces
Category search not clear at start up.
Define spaces with different functions or requirements
Designers have focussed on saving screen space and not providing adequate labelling.

10. Symbol in space indicates purpose, but has none
Signs
Use of symbolic metaphors
Crossroads at middle left of screen is not obvious. Crossroads is not active it is a metaphor for nothing
Conceptual
Clearly separate from other objects
Glasgow directory symbol at side of space may be mistaken for another information space
Define Important Spaces
Blue background cross roads lacks function yet is clearly defined for no reason
Integration with signs
Would expect some function from Glasgow directory symbol (the crossroads), but none is provided

11. Signs: directional colour metaphors not always used
Signs
Use of Colour Metaphors
Buttons are arbitary grey. Minimal use of colour (3). Colour used in both informational and directional signs, but the user may not realise this.

12. No info on how long a route will take
Signs
Clear marking of distance/time to reach destination.
No markings of steps involved or time (3). VRML: no markings of distance or time (2)
Clear Mapping
VRML: balloons help identify buildings but no indication of distance and time to reach the destination is provided..

13. Approach to new information spaces not always clear
Signs
Articulation of Space
Not always clear when options are available.
Conceptual and Physical Structure
Clearly Marked Paths
Paths between spaces are not clearly marked.
Differentiation in paths
No clear paths between information spaces. Several paths exist to achieve same goal and this creates potential ambiguities.
Clear approach
No warning of approach (2).
Clear Arrival
Building selector, no indication of approach.

14. Info spaces have different interaction styles
Signs
Consistency
Steet option in VRML may be expected to produce a drop down list as other options do.
Define spaces with different functions or requirements
Category search not clear in VRML world as it differs in the menu, can be misleading. 2D/3D operate very differently.

15. Most likely to be used easily by Glasgow residents
Conceptual
Should relate to user experiences
Best suited to people with experience of Glasgow (3).
Clear arrival
Arrival in VRML and ariel view confusing, especially to those without knowledge of Glasgow.

16. 2D/3D spaces far apart
Conceptual
Short Distances within related paths
Information spaces shows data in building selector too far from other spaces.

17. 2D landmarks badly defined
Conceptual
Clarity of function and content.
The interactive landmarks are not always clear. Red dots Category search provide more information than expected. SF: user expects to be able to click on streets in current region. SF: contains content which is unexpected. Map click 2D to 3D not good.
Landmarks and Route Awareness
Landmarks are not clear (3). Search option not obvious as SF.

18.No markings of optimal route
Signs
Mark optimal routes
No marking provided (4).

19. No explanation of colour coding of spheres
Interpretation:
Signs
Minimalist
Balloons in VRML are too vague.
Conceptual
Clarity of function and content.
Coloured balloons are not good or clear.

20. Lack of Details / Buildings difficult to distinguish/ Buildings need texture
Conceptual
Define Important Spaces
VRML view not clear. Model space lacks detailed info, balloons hard to find, date feature difficult to spot.
Appropriate mapping of physical to conceptual stucture.
Not possible to know if VRML world will benefit people in the real environment due to lack of textures, colours etc. VRML view just contains object, no enhancement (2).
Clearly Visible
VRML view is vague.
Buildings not identifiable (5).
Clarity of function and content.
Lack of details on buildings can cause problems (not issue with churches etc).
Clearly Marked Paths
Paths are slightly different colour, but the same as Clyde river (bad).
Differentiation in Paths
Some of the paths in model are not clearly marked.

20. Lack of Details / Buildings difficult to distinguish/ Buildings need texture
Signs
Visibility of environment
Types of building not seperable(2).
Consistency
Model Space: signs not distinct for buildings.
Use of color metaphors
No colour metaphors except balloons (2). Minimal use of colour (3). VRML: problems with info signs as they are all the same colour. VRML space uses informational color coding but has no key.
Use of symbolic metaphors
Buildings too similar in colour.
Clear approach
Buildings all look the same.
Clear Transition
No routes or clear transitions in VRML due to similarity in buildings.
Uniquely mark objects
None are uniquely marked (3). Not all are well marked (3). Not clear what buildings are being singled out. VRML: buildings are not highlighted in anyway (3). Problem seperating where a building begins and ends as no seperation between building and landmark information..
Uniquely mark locations
Buildings are all the same (3).

21. No Landmarks or little detail /no buildings of interest marked

Signs

Visibility of Signs:

Highlighted buildings are not always visible.

Uniquely mark objects

Problem seperating where a building begins and ends as no seperation between building and landmark information.

Appropriate level of Signage

When using the date line and category search, the VRML menu sometimes becomes difficult to see as areas in the world are being highlighted.

Inconsistency

Buildings currently viewed is not highlighted.

Conceptual

Appropriate mapping of physical to conceptual stucture.

VRML view just contains object, no enhancement (2).

Should relate to user experiences

Building should differ from landmarks.
Landmarks difficult to distinguish.

Clearly Visible

Colour coding of balloons not buildings (2).
Not easy to identify individual landmarks (2).
VRML: does not indicate current building.

Clearly separate from other objects

Problems distinguishing landmarks (3).
Not enough seperation of orientation only landmarks.

Clarity of function and content.

Lack of details on buildings can cause problems (not issue with churches etc).

Emphasise key landmarks

Problems separating landmarks rest of environment (3).
Lack of colour or textures makes this difficult (1).
No differentiation major/minor.
In VRML no marking of the landmark you have selected (2).

Landmarks and Route Awareness

Landmarks not clear (3).

22. No indication of Direction/Problems maintaining Directional Orientation
Signs
Use of symbolic metaphors
No NSEW arrows (2).
Use of language metaphors
NSEW metaphors missing.
Clear markings of distance/time to reach destination
No labels to indicate direction.
Clear marking of direction
Ok, but no comprehensive indicators (2). No indication of direction (3). No visible result can cause problems. Arrows in VRML are not clear. No indication of direction in model view. VRML: no informaiton on which way the user is going. Directional signs for buildings are hidden unless the user scrolls to the bottom of the list. VRML: difficult to see where the red arrows relate to, whether it is direction or region on map.
Appropriate Level of Signage
No NSEW indicators in VRML.
Clear location information
Arrows in VRML are arbitary no metaphor or no NSEW (3).
Conceptual
Clearly define spaces with related functions.
VRML navigational arrows do not correspond with 2D map.
Awareness
Not clear which direction you are facing when enteringVRML.

23. Approach and Arrival not clear in VRML
Signs
Use of language metaphors
If q user selects the street option in VRML the sign is obscured as roof tops are white like the sign.
Clear initital encounter
No clear indication of this (2).
Clear approach
VRML tool not clear Approaching signs is limited, lack of feedback It may be better to have more steps in movement to suggest arrival. Arrival in VRML not clear.
Conceptual
Clearly separate from other objects
It is not obvious that people have arrived at objects/locations in VRML view.
Clear approach
No warning of approach (2). Approach to carrying out users goals in ariel map and VRML not clear.
Clear Arrival
No indication of arrival at the destination (4). Arrival VRML and ariel view confusing, especially those without knowledge of Glasgow.
Clear within path markings
Most except VRML are clear.

24. Lack of Signs/ Poor Quality of Signs/Signs being obscured
Signs
Visibility of Signs
Balloons are obscured by buildings (2). VRML: visibility of informational signs can be obscured (3).
Visibility of environment
Problems with signs being too small (or not visible) in model space (2).
Consistency
Model Space: signs no distinct for buildings. Category/date search balloons not consistent. Balloon sizes not good (further = bigger).
Inconsistency
VRML: signs required to complete task are not differentiated in any way.
Definition of space
VRML: no markings except above provided.
Difficult to see balloons in VRML view.
Use of color metaphors
Signs not clear in VRML. VRML: problems with info signs as they are all the same colour. Colour used in both informational and directional signs, user may not realise this. Use of red in VRML window for directional signs adds to inconsistency. VRML space uses informational color coding but has no key. Colours merge into one another causing confusion if multiple options selected from tourism menu.
Use of language metaphors
VRML space when categories selected balloons not obvious until user gets really close. If user selects street option in VRML the sign is obscured as roof tops in VRML are white like the sign.
Clear marking of distance/time to reach destination.
VRML: no markings of distance or time (2). No labels to indicate direction.
Clear Marking of Direction
ok, but no comprehensive indicators (2). No indication of direction (3).
Clear location information:
Lack of information in VRML model.
Mark optimal routes
No marking provided (4)
Clear Mapping
VRML: balloons help identify buildings but no indication of distance and time.

24. Lack of Signs/ Poor Quality of Signs/Signs being obscured
Minimalist
Balloons are too vague.
Positive Feedback
Navigation towards buildings may confuse as balloons get smaller as the user approaches.
Appropriate Level of Signage
No signs.
Conceptual
Appropriate mapping of physical to conceptual stucture.
VRML view just contains object, no enhancement (2).
Clearly Marked Paths
No street signs in VRML.
Integration with signs
VRML: signs provided but not integrated with routes.
Clearly Visible
Balloons often difficult to see.
Integration with signs
No signs provided for navigation.

25. Building of Route Knowledge not possibe
Signs
Mark Optimal Routes
No markings provided (4).
Clear marking of route
VRML not clear:No good markings for routes.
Clear approach
Buildings all look the same. Approaching signs is limited, lack of feedback. Arrival in VRML is clear.
Conceptual
Landmarks and Route Awareness
No routes, problems getting to buildings (2). VRML: landmarks do not integrate in with routes users may be taking. VRML: space contains no paths for users to follow. VRML world has no coding to aid in idenfiying paths. VRML: no paths, hence no differentiation can take place.
Clear within path Markings
Would be beneficial in VRML model. VRML not clear.
Short distances within related paths
Paths not clearly marked.

26. Street finder: Finds buildings not streets

Signs

Appropriate for Users

Results of SF ambigious.

Conceptual

Appropriate mapping of physical to conceptual stucture

SF: user expects to be able to locate streets especitally in VRML.

Mutual Exclusion

SF: buildings are not streets and hence should not be grouped together.

Clarity of function and content.

SF: user expects to be able to click on streets in current region.

Clearly separate from other objects

SF: user may expect to be able to click on street and be taken there.

27. User expects Street Finder + Landmark selecting to locate landmark (clear mapping)

Signs

Clear Mapping

Cannot use street finder results (properties plus buildings) to go to location.

Conceptual

Appropriate Mapping of physical to conceptual structure

Street finder: expect highlighting of main attractions.

28. Map: No Path Structures

Conceptual

Appropriate mapping of physical to conceptual stucture.

Map is difficult due to lack of path structures(2).

Should relate to user experiences

Map not clear.

29. Category Search: Related information located far away
Signs
Use of symbolic metaphors
Category search iconic map, users have to figure out which the relation between the building and the picture which acts as a directional sign.

Appendix C

Design Study

This appendix contains the data from the design study in chapter 6. It contains tables of the scores from the questionnaires, sketch maps, the journey maps and copies of the questionnaires used.

Questionnaire: Environment 1 : Large

Key: Mode = Mode. Med = Median. Mean = Mean and Sam = number of samples. The maximum for environment one is 22.

	Mode	Med	Mean	Sam
1. It is easy to understand how the information is organised within the exhibition.	2	2	2.09	21
2. To learn from the exhibition is easy.	2	2	2.65	17
3. The exhibition is engaging.	2	2	2.33	18
4. The content of the exhibition is comprehensible.	2	2	2.42	19
5. The exhibition stimulates thinking.	2	2	2.5	20
6. I don't feel tired at all.	2	2	1.89	19
7. The exhibition is sterile	2	2	2.64	14
8. The maps helped me find my way around.	4	2	2.69	22
9. The maps helped me gain an overview of the exhibition.	2	2	2.04	21
10. The floor colours helped me gain an overview of the exhibition.	4	4	3.81	16
11. On arriving in the exhibition I was able to comprehend the size of it.	4	4	3.7	20
12. The paths made it easy for me to find my way around.	1	2	1.74	19
13. The paths reflected where I wanted to go.	1	2	2.2	15
14. The signs helped me identify areas of the exhibition.	2	2	1.62	21
15. The signs reflected where I wanted to go.	2	2	1.92	14
16. The paths made it clear when I was entering or leaving parts of the exhibition.	1	2	2.4	15
17. The signs made it clear when I was entering or leaving parts of the exhibition.	2	2	1.81	21
18. I Felt overwhelmed by the amount of information presented to me.	4	4	3.06	18
19. I did not feel lost within the exhibition.	2	2	2.55	20
20. *The paths made it easy for me to find my way around.	2	2	2.39	18
21. The signs helped me identify areas of the exhibition.	2	2	2.84	19
22. The paths reflected where I wanted to go.	1	2	1.61	21
23. The signs reflected where I wanted to go.	2	2	2.17	18
24. The paths made it clear when I was entering or leaving parts of the exhibition.	2	2	2.69	16
25. The signs made it clear when I was entering and leaving parts of the exhibition.	2	2	1.81	21
26. I did not feel lost within the exhibition.	2	2	1.73	22

Table c-1. The questionnaire scores for the large environment.

Environment 2: Small

Please note certain values do not appear in the table as they were not relevant in this particular context. Also although the same question number is used for environment 1 & 2 the actual numbers used in the questionnaires may vary.

Key: Mode = Mode. Med = Median. Mean = Mean and Sam = number of samples. The maximum for environment two is 18.

	Mode	Med	Mean	Sam
1. It is easy to understand how the information is organised within the exhibition.	2	2	2	17
2. To learn from the exhibition is easy.	2	2	2.71	17
3. The exhibition is engaging.	2	2	2.07	15
4. The content of the exhibition is comprehensible.	4	4	3.07	16
5. The exhibition stimulates thinking.	2	2	2	15
6. I don't feel tired at all.	2	2	2.53	15
7. The exhibition is sterile	4	4	3.25	16
8.				
9.				
10.				
11. On arriving in the exhibition I was able to comprehend the size of it.	2	2	2.375	16
12. The paths made it easy for me to find my way around.	4	4	3.1875	16
13. The paths reflected where I wanted to go.	2	2	2.875	16
14.				
15.				
16.				
17.				
18. I Felt overwhelmed by the amount of information presented to me.	4	4	3.143	14
19. I did not feel lost within the exhibition.	2	2	2	16
20. *The paths made it easy for me to find my way around.	2	3	3.125	16
21. The signs helped me identify areas of the exhibition.	2	3	3.125	16
22.				
23.				
24.				
25.				
26. I did not feel lost within the exhibition.	2	2	1.6	15

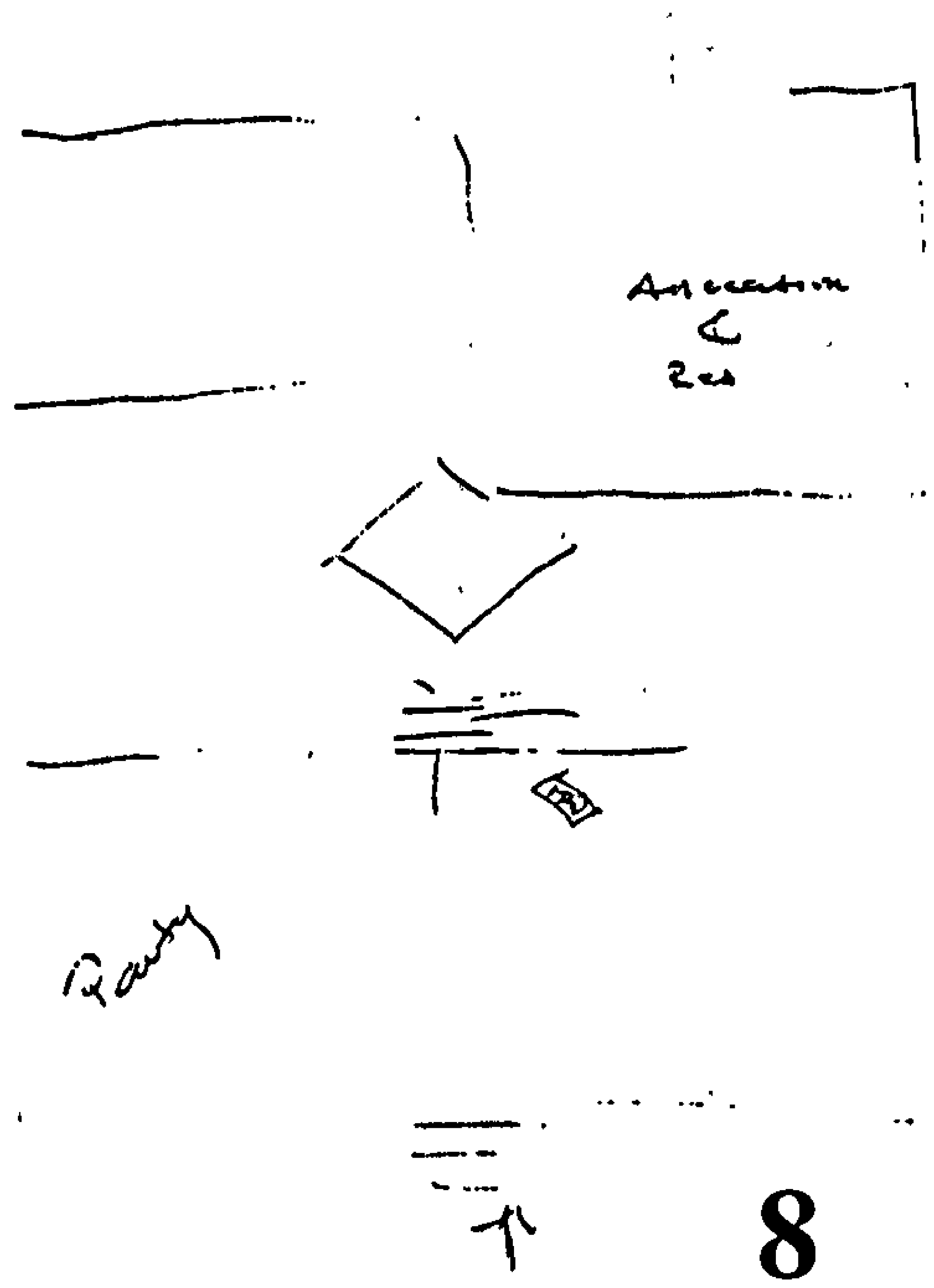
Table c-2: The questionnaire scores for the small environment.

Sketch Map Scores

Sweden Study Map Analysis																
		Objects											Relative Object Score			
Subject	Type	Maps	Stairs	Named	Unnamed	Between	Fire	Central	Archways	Trees	T		Name	Unnamed	Stairs	Fire
8	0	1	2	2	5	4		1			15		1	5	2	
9	1		1		5	4		1			12			5	1	
10	1		3		5			1			10			5	3	
11	0				5	4		1			10			5		
15	1	2		1	5			1			10		2	5		
17	2		4		5						11			5	4	
16	0		3		5			1			9			5	3	
18	1			5	5	4					15		5			
19	2		3		5						10			5	3	
20	1		3		5	4		1	7		21			5	3	
26	1		2		5	4		1			13			5	1	
41	0		2	3	4	2			4		15		1	4	2	
45	1		2		5	4	2	1			15			5	2	1
40	1		2	5	5	4			8		25		5	5	2	
38	1		1	3	4	4					13		2	5	1	
35	2		3		5	4			6		20			5		
34	2		3		5						10			5	3	
33	2		2	1	5	4	1				15			4		
28	1		3	1	5	4					14		1	5	3	
24	1		4		5	2				1	13			4		
Median		2	3	3	5	4	1.5	1	6.5	1	14		2	5	3	1
Number		2	17	8	20	14	2	9	4	1			7	19	14	1

Table c-3. The above table provides information on the relative scores for each map. The Type/path column represents the type of map found. 0= non-path 1= path 2 = numerical sectors.

Sample Sketch Maps



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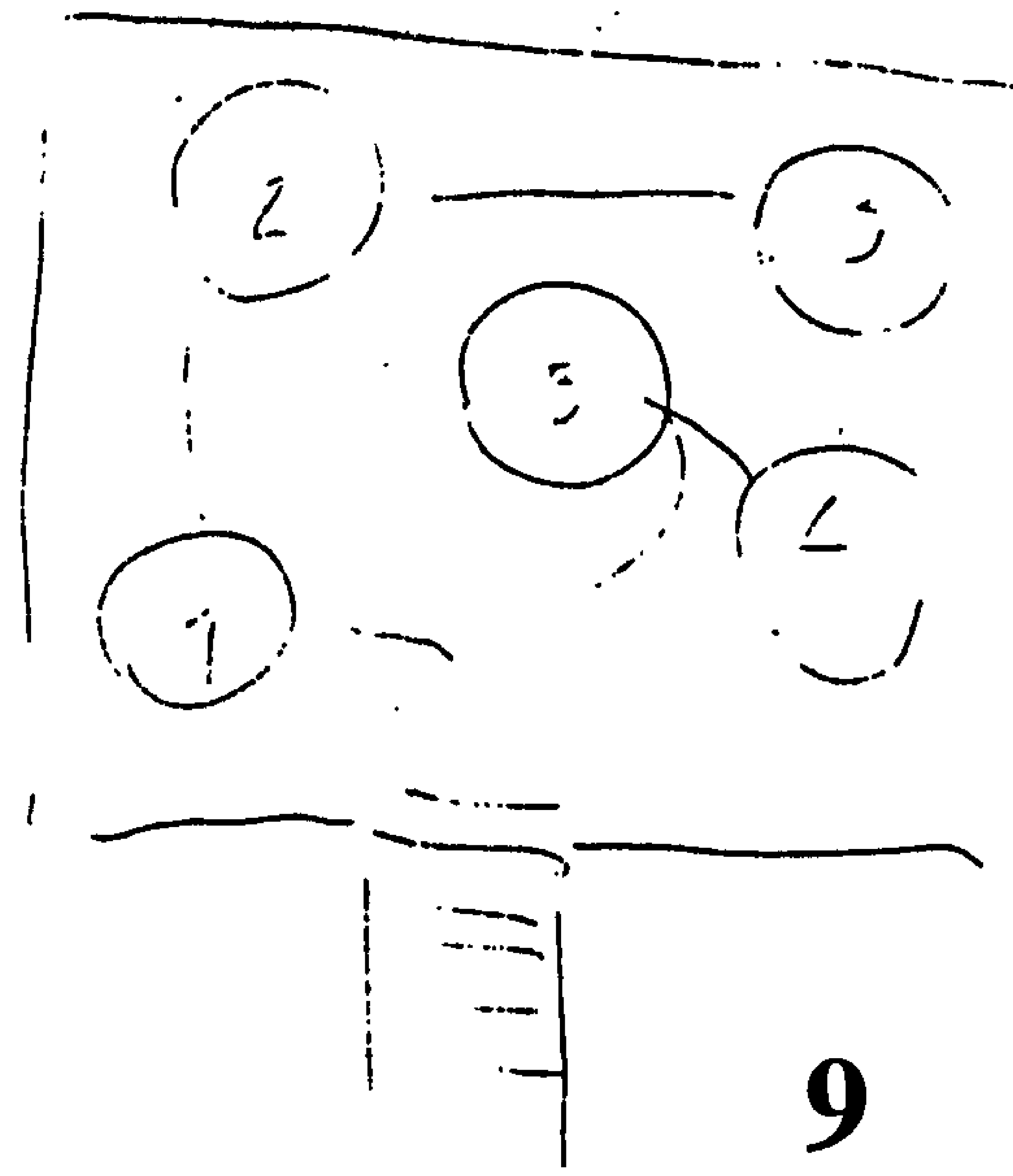

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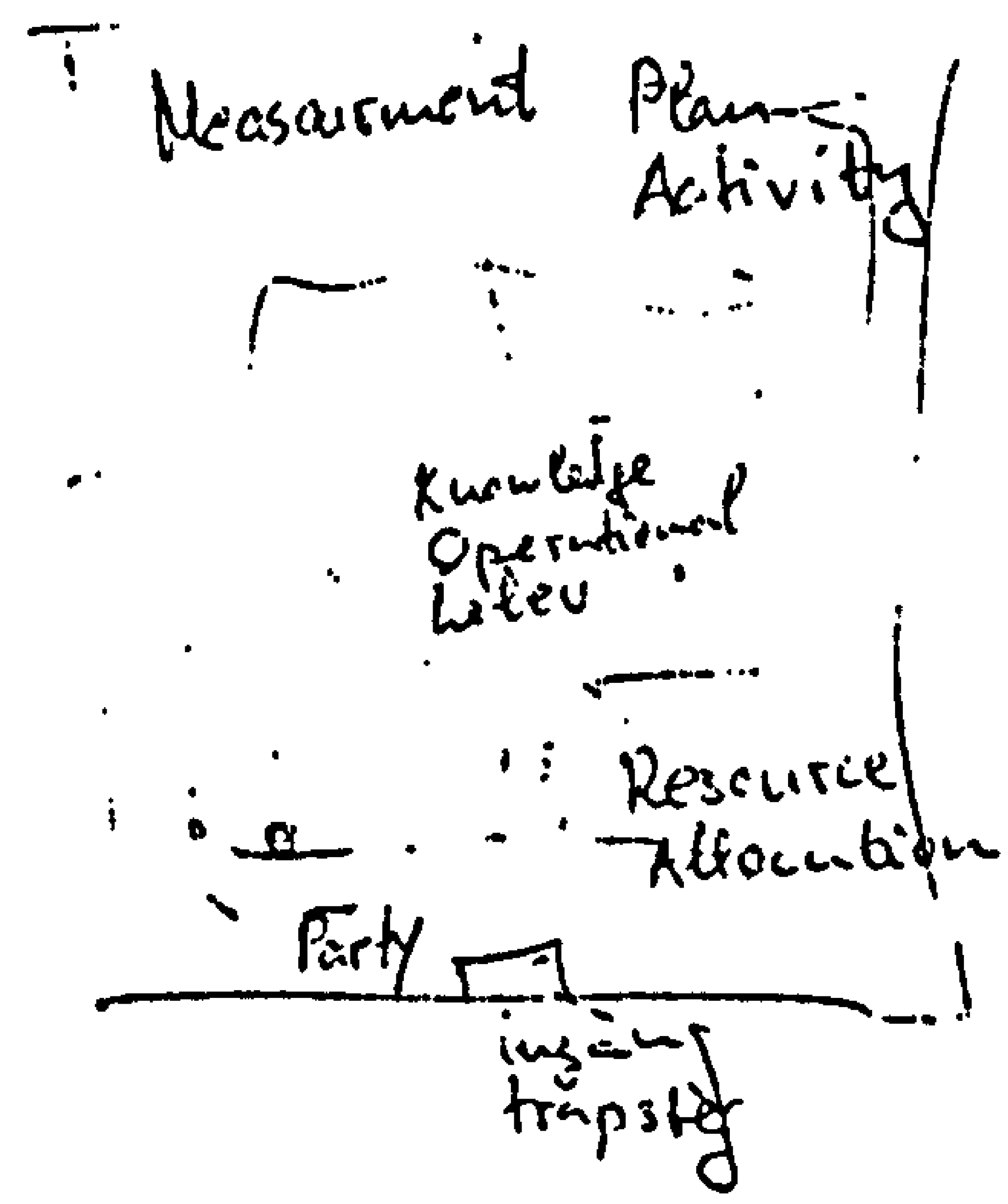

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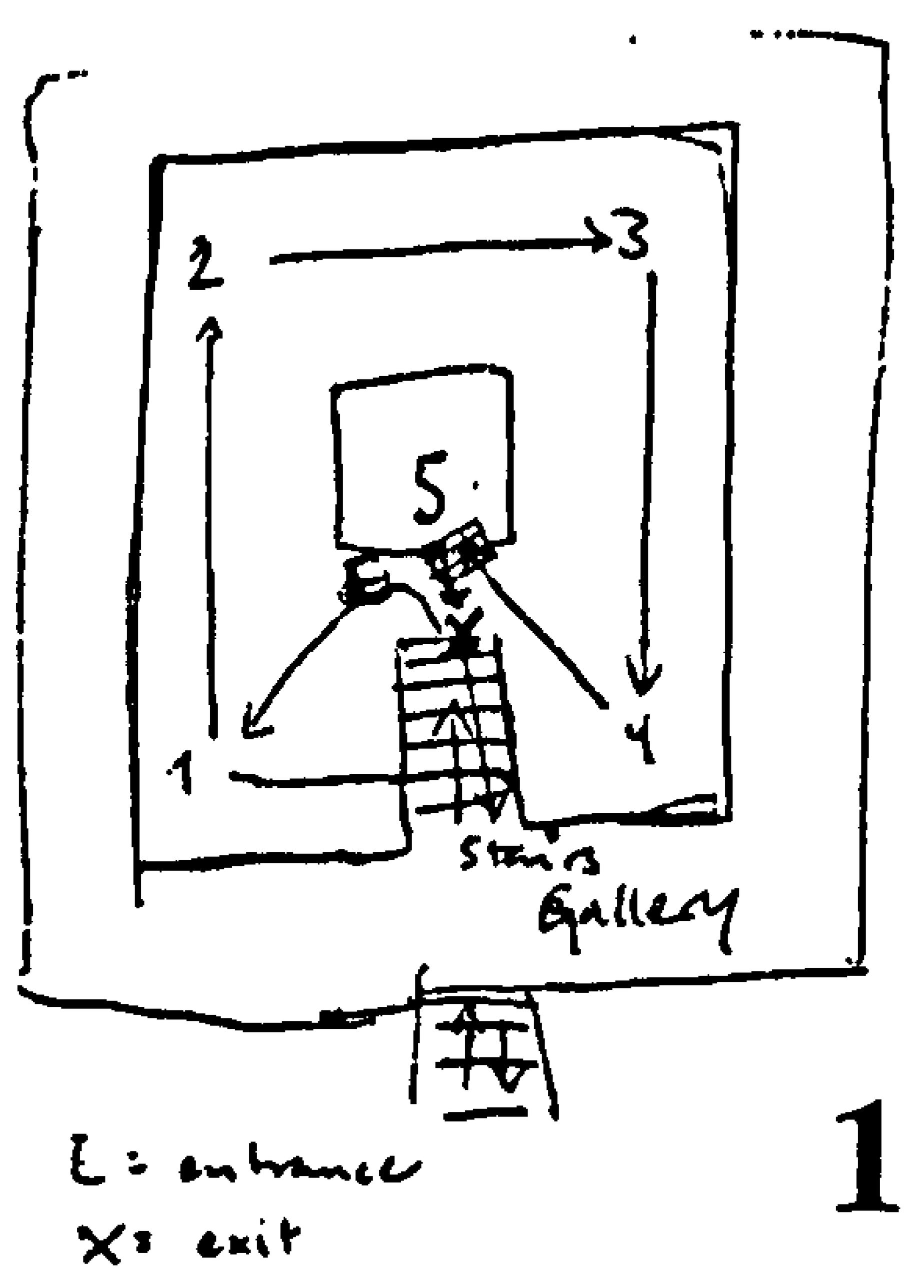

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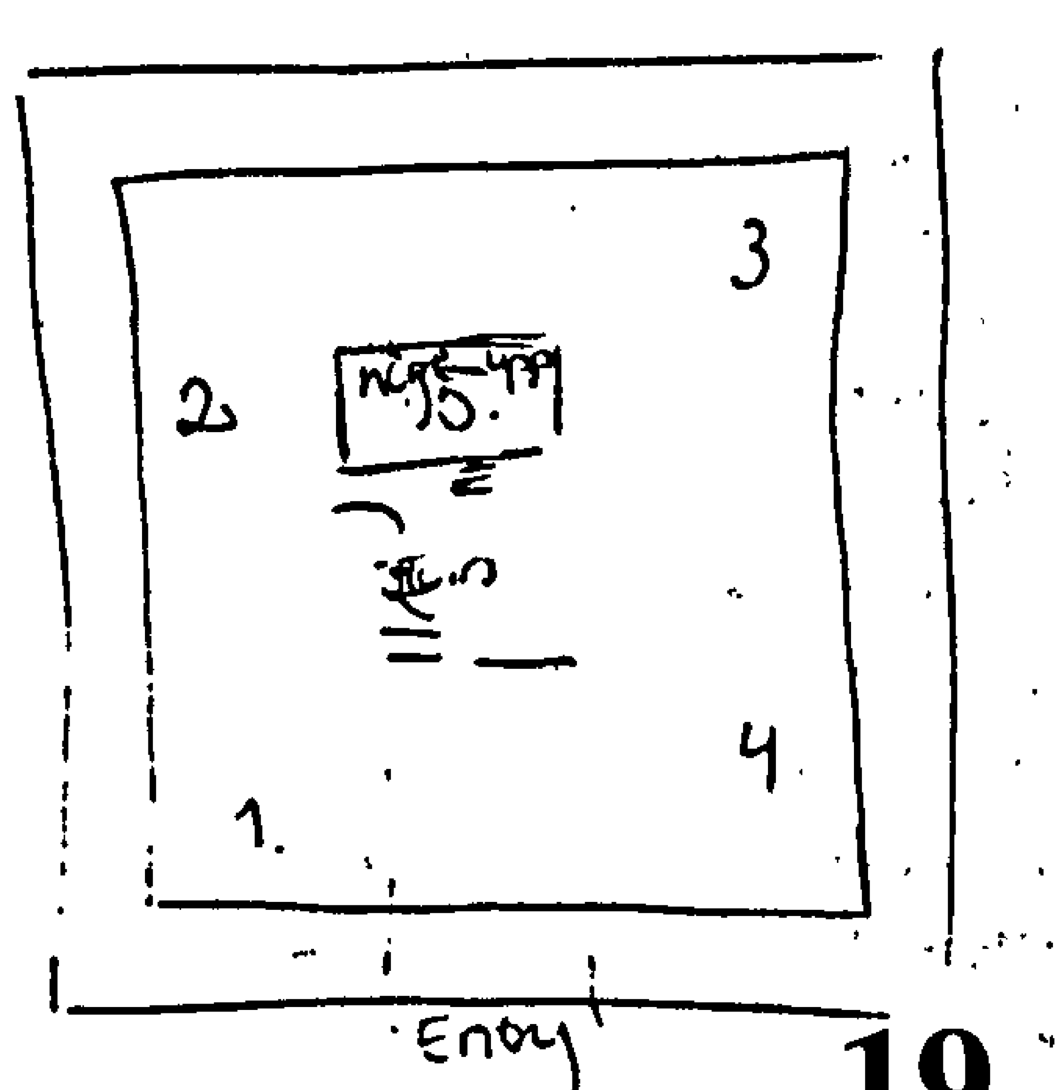

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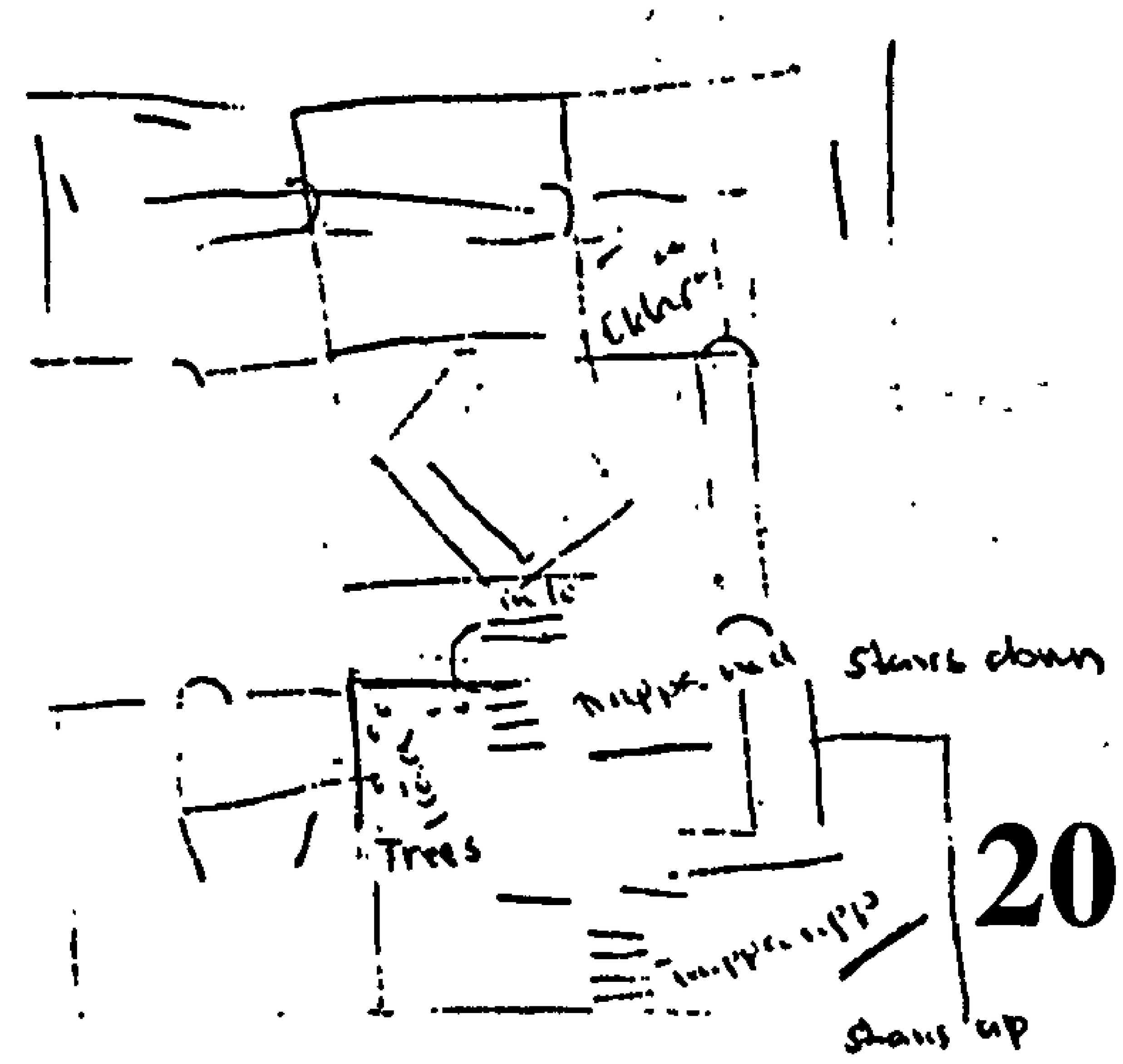

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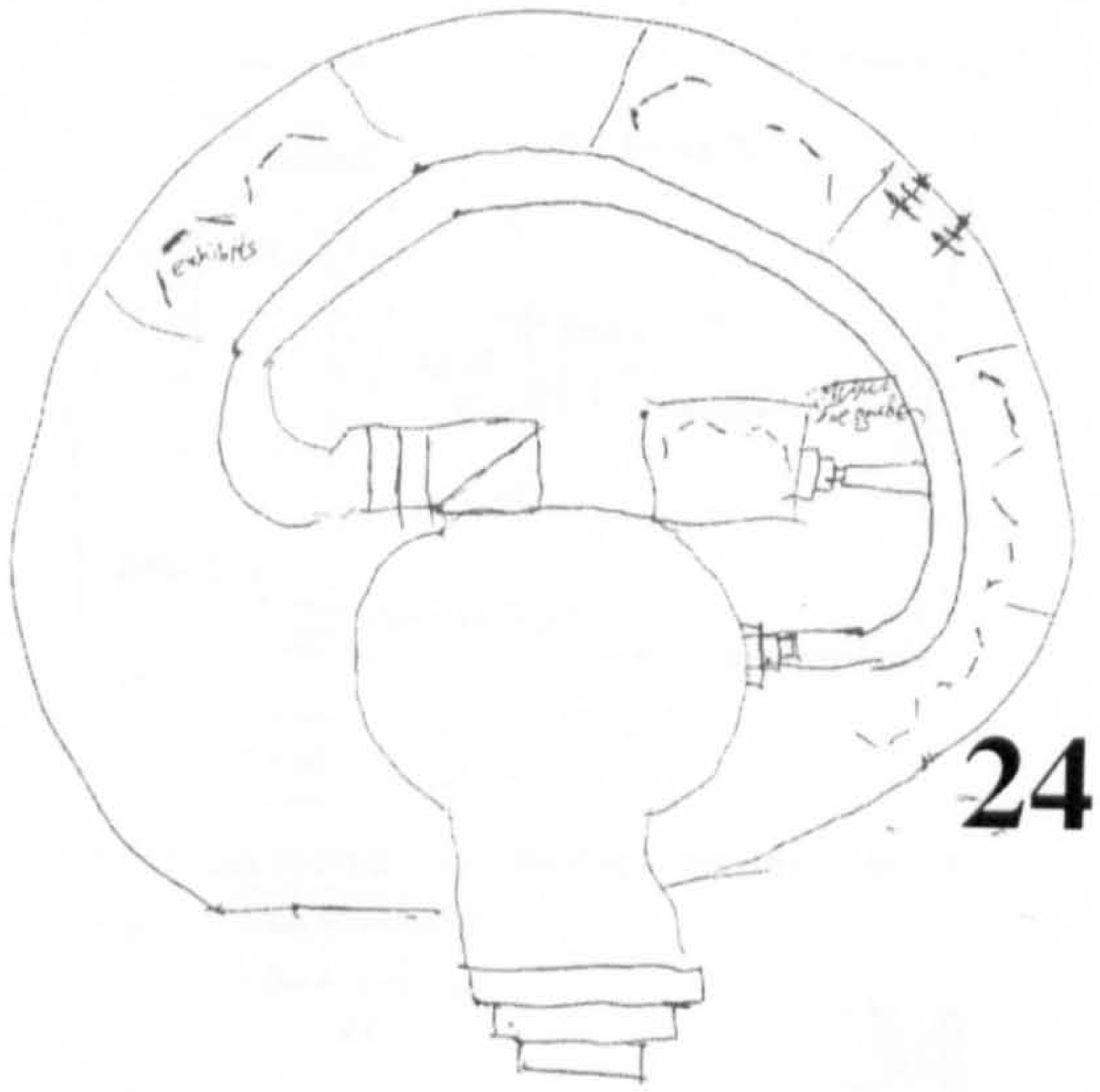

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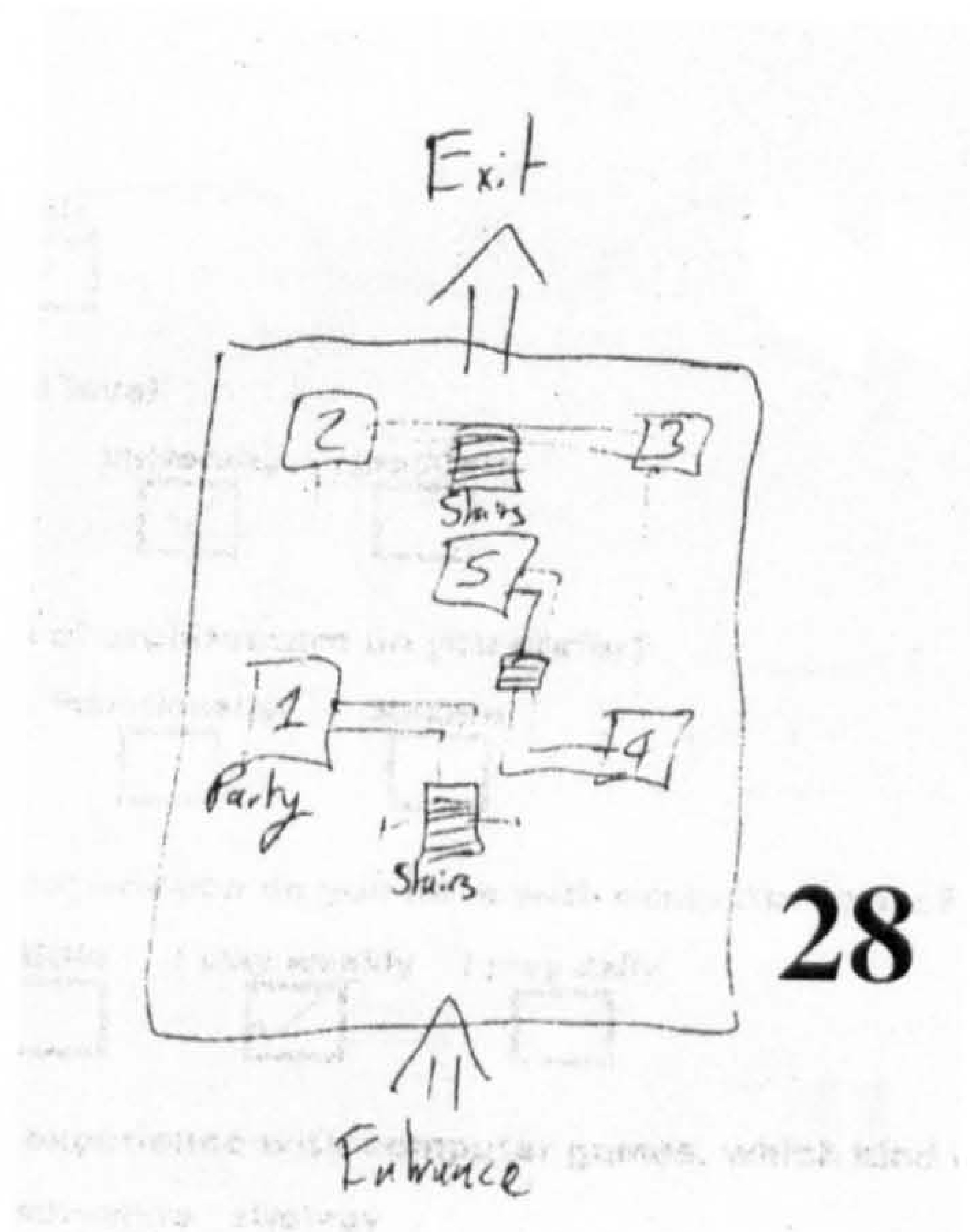

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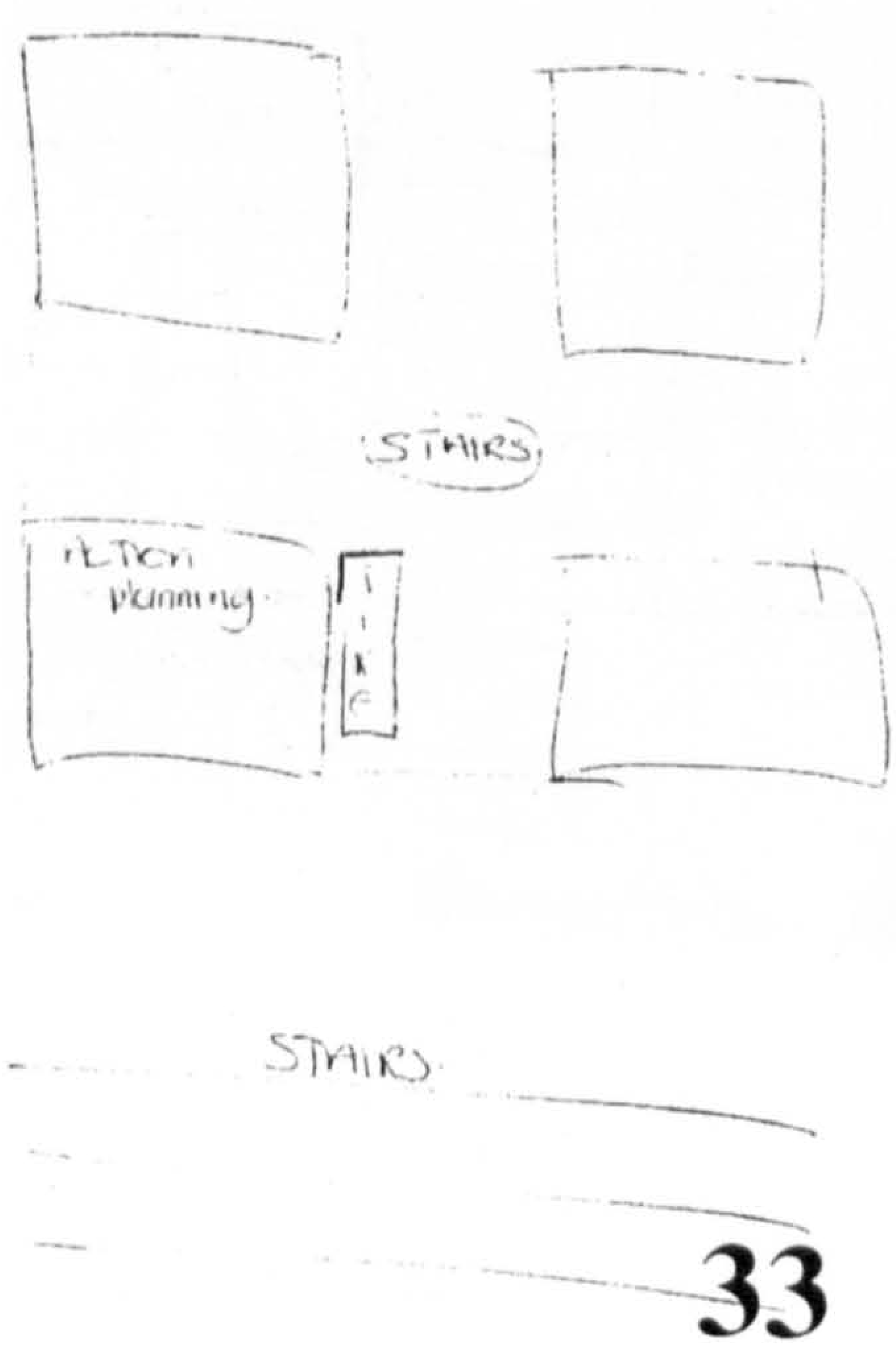

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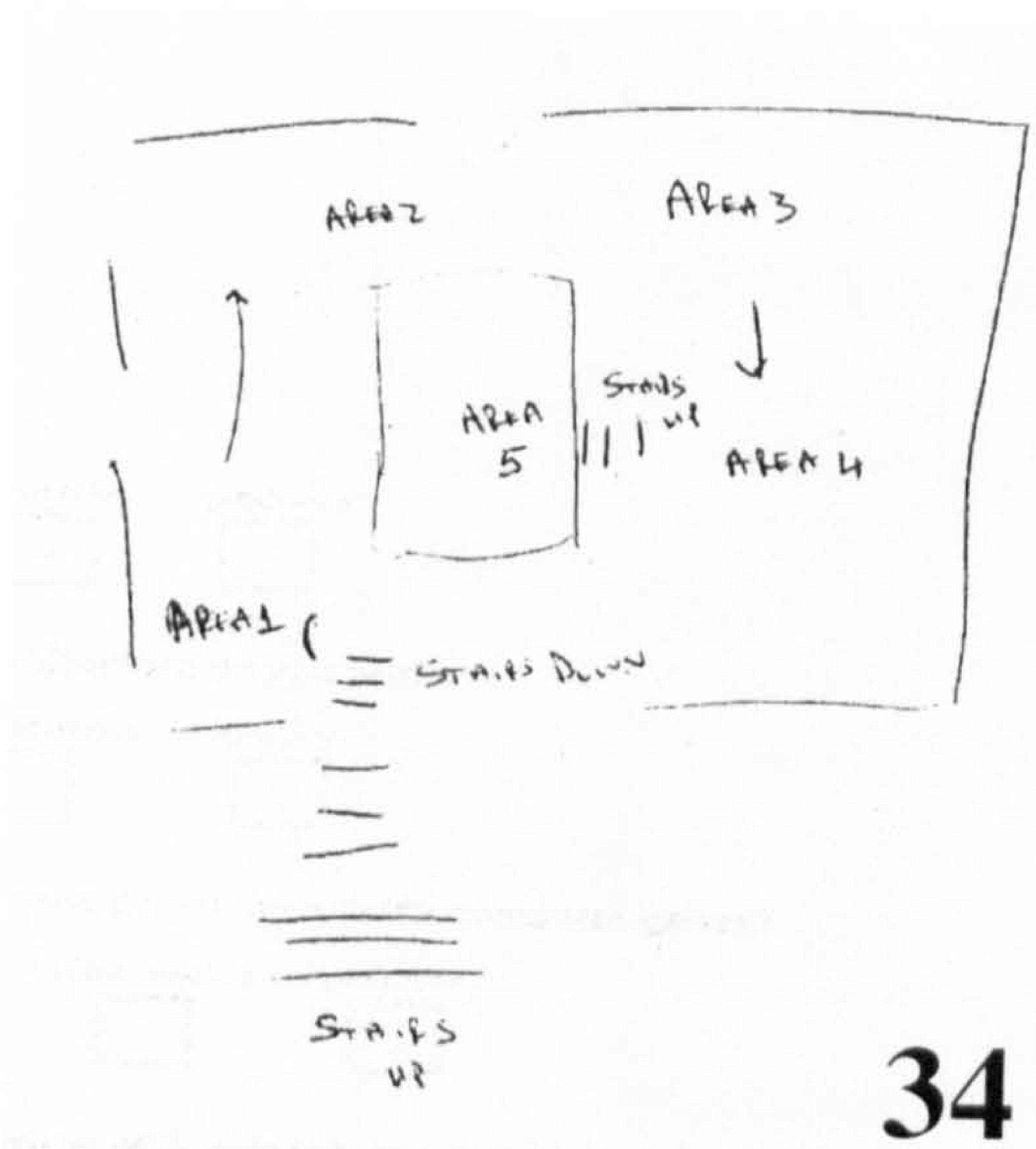
Sample Sketch Maps



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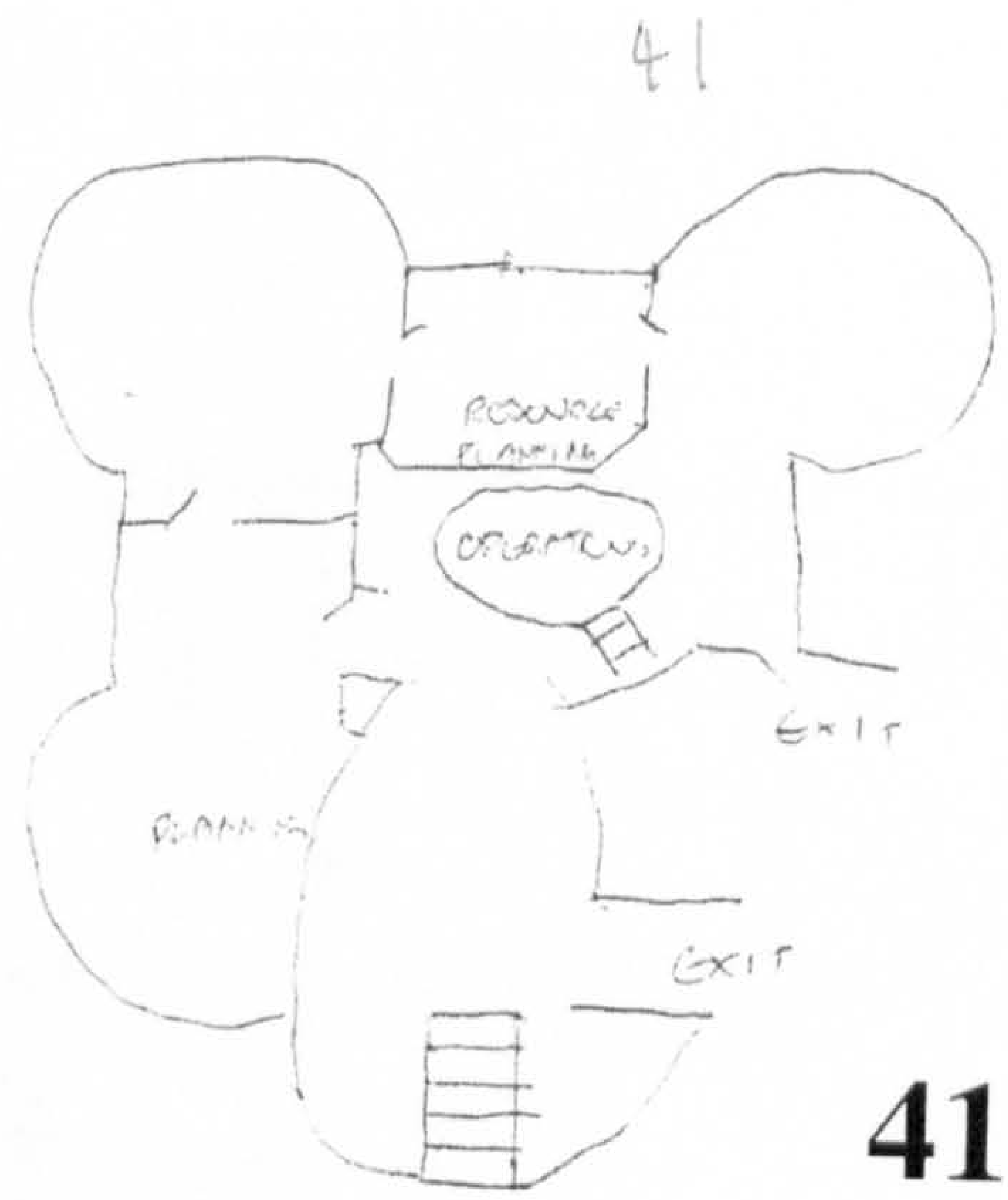

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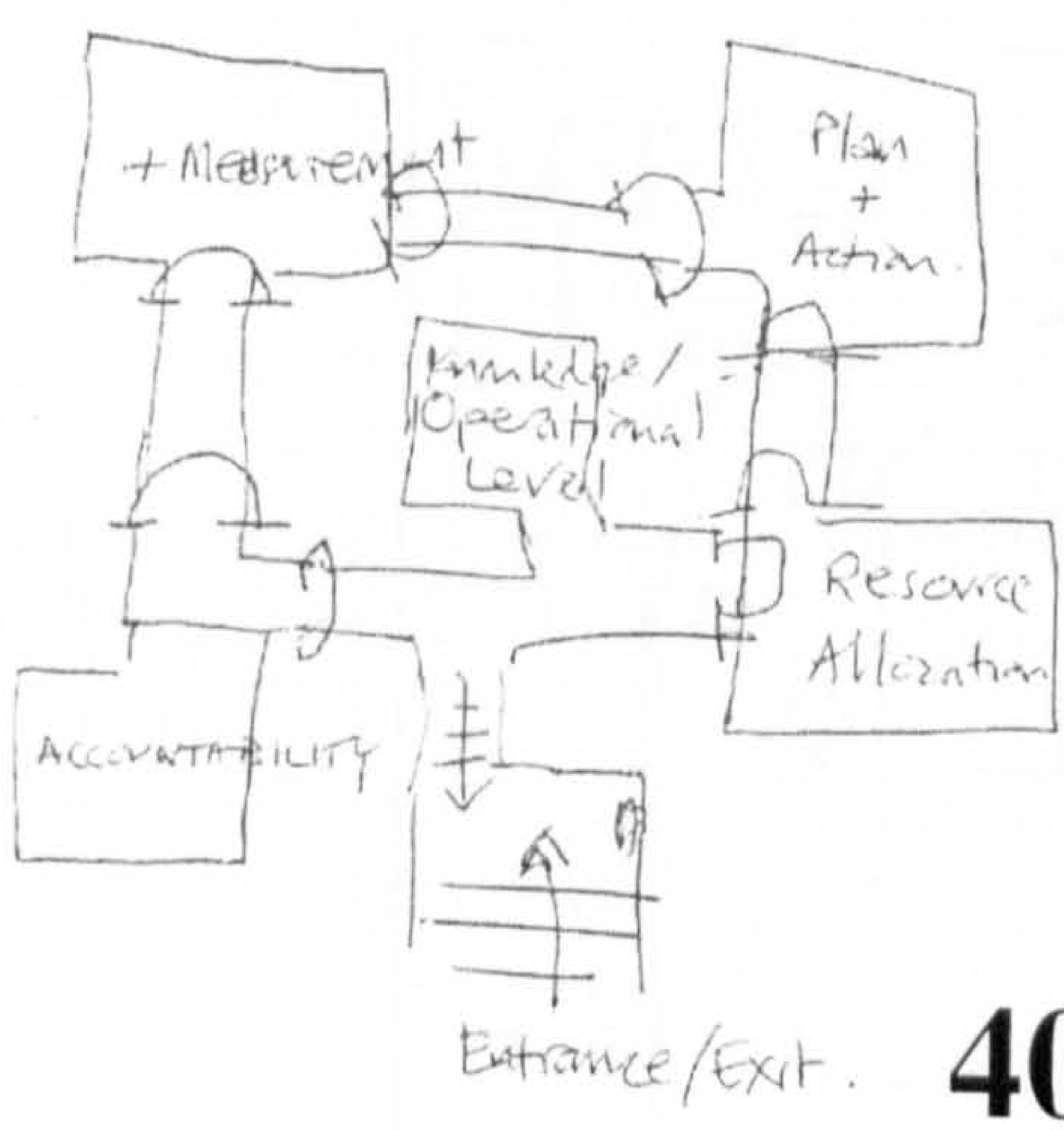

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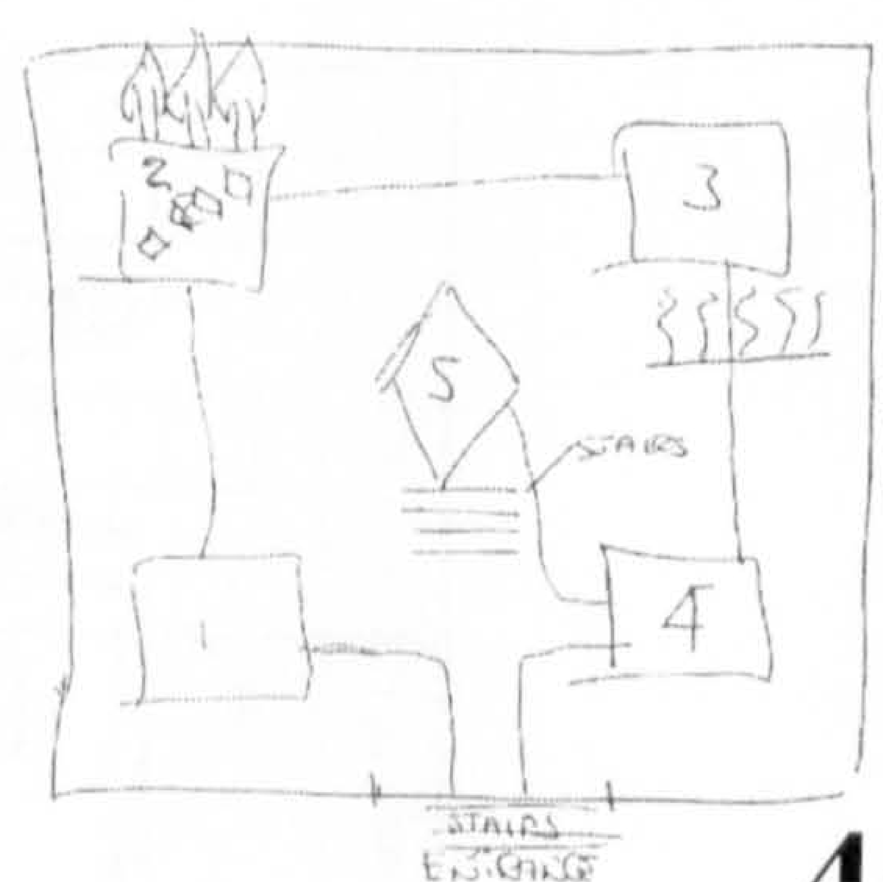

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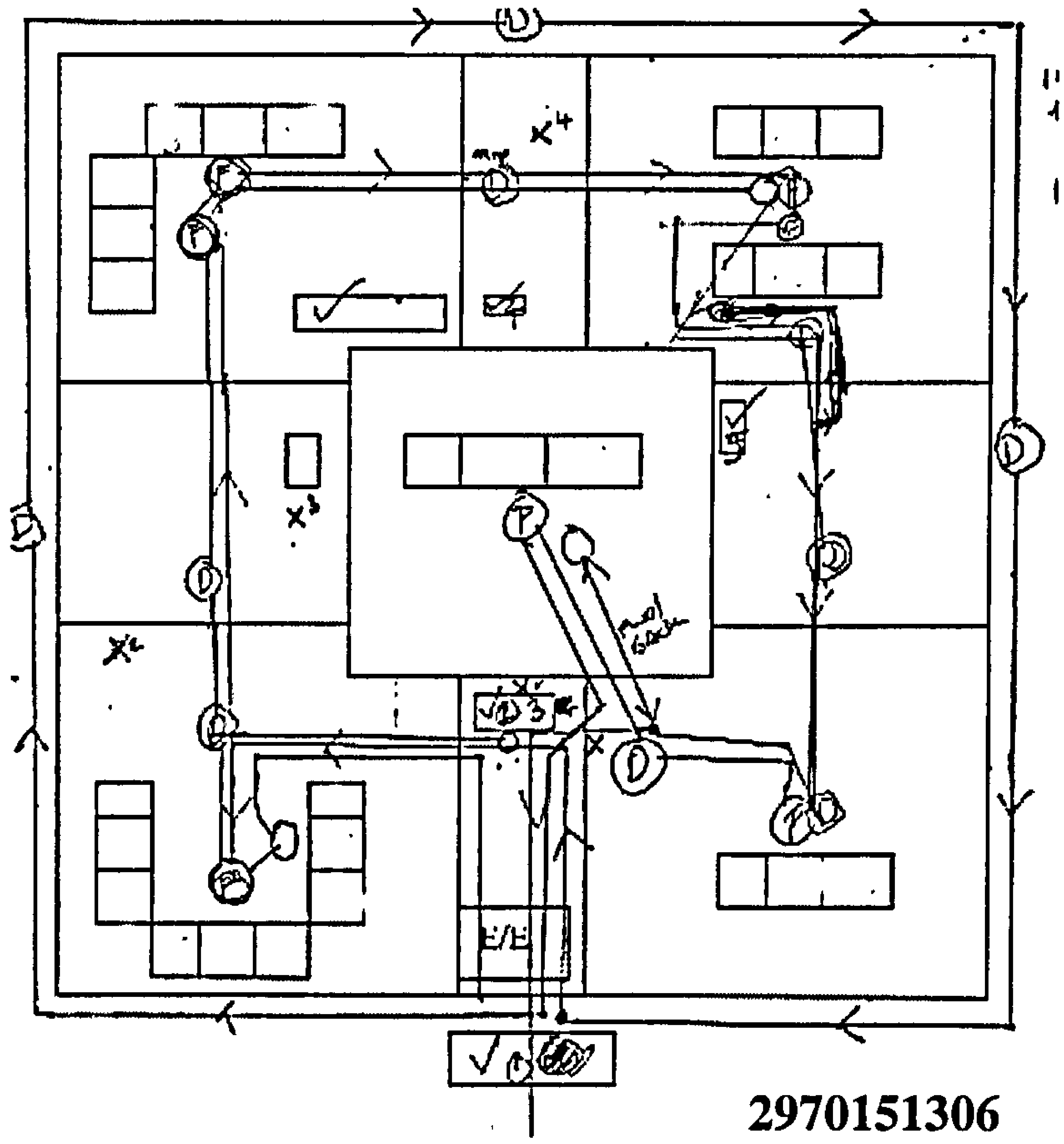
Journey Maps



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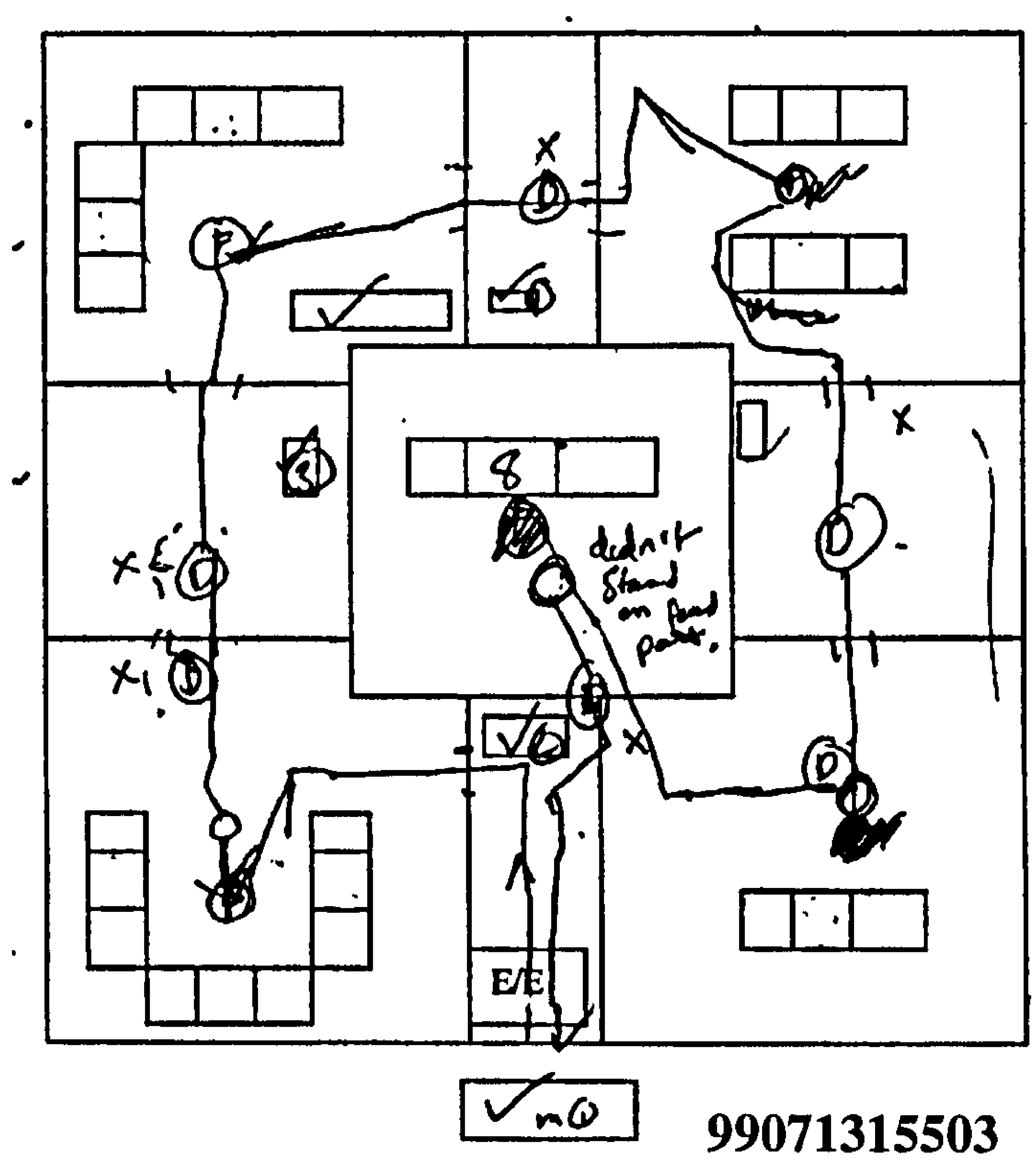

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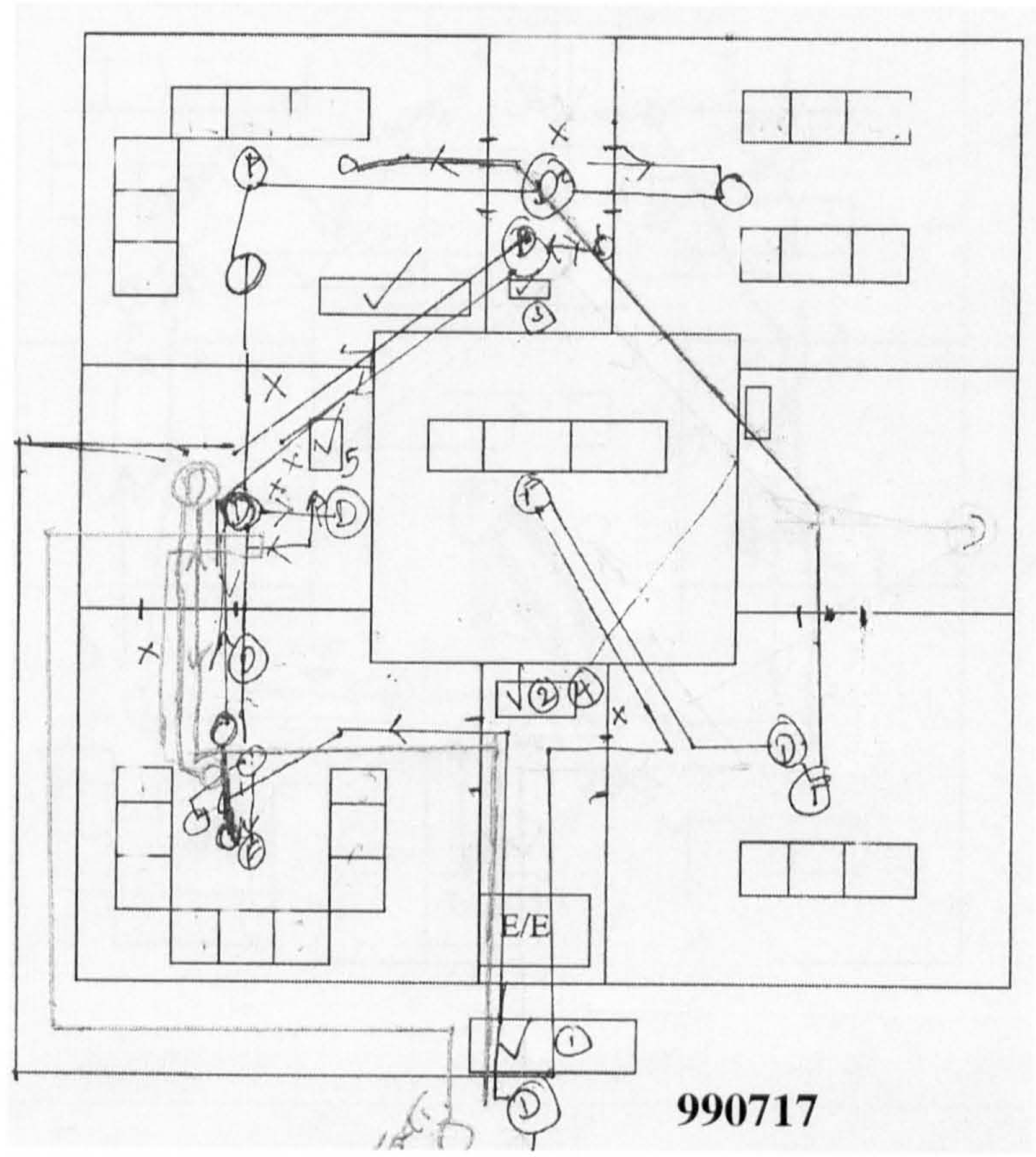
Journey Maps—Exploration Tasks



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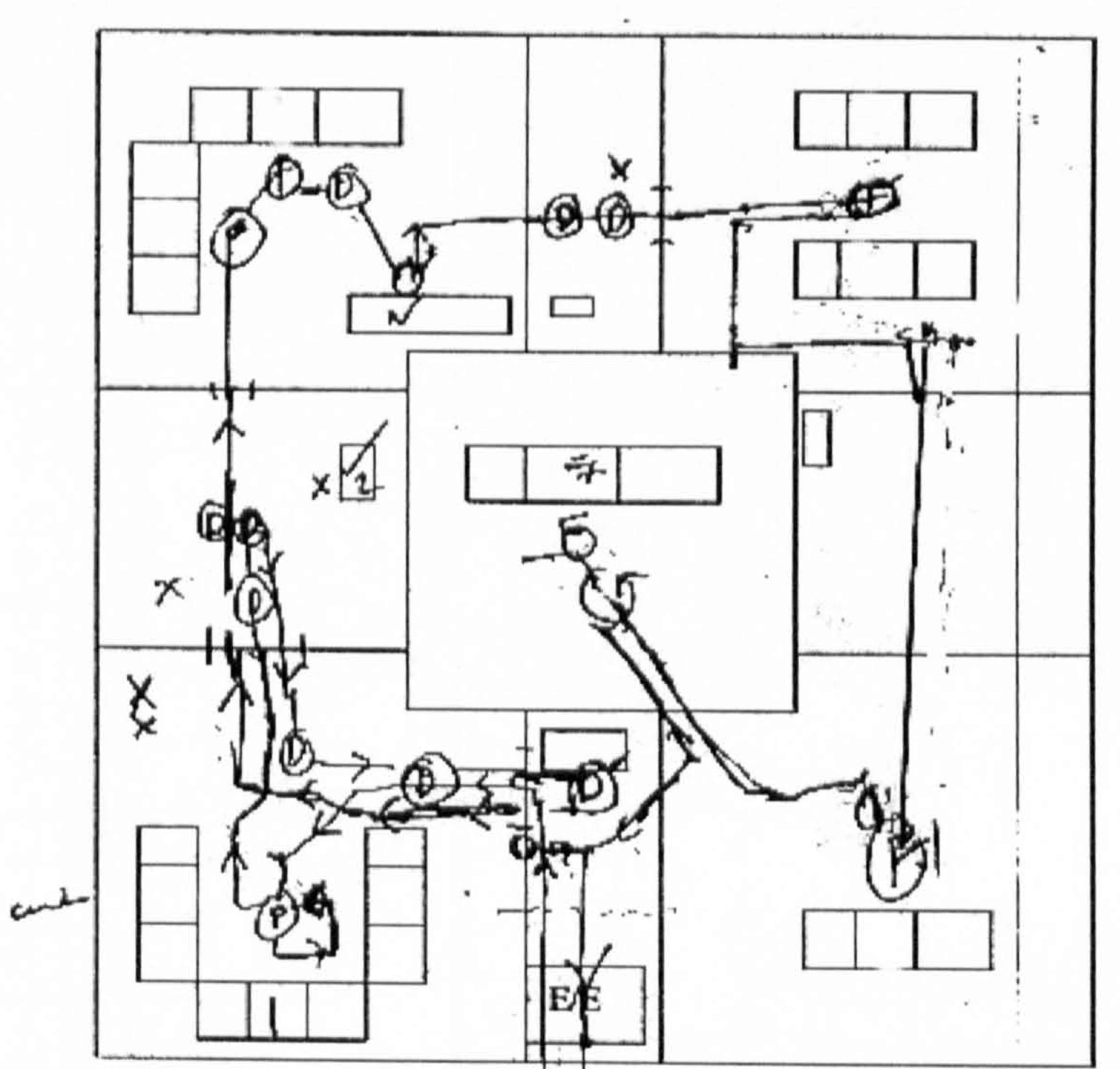

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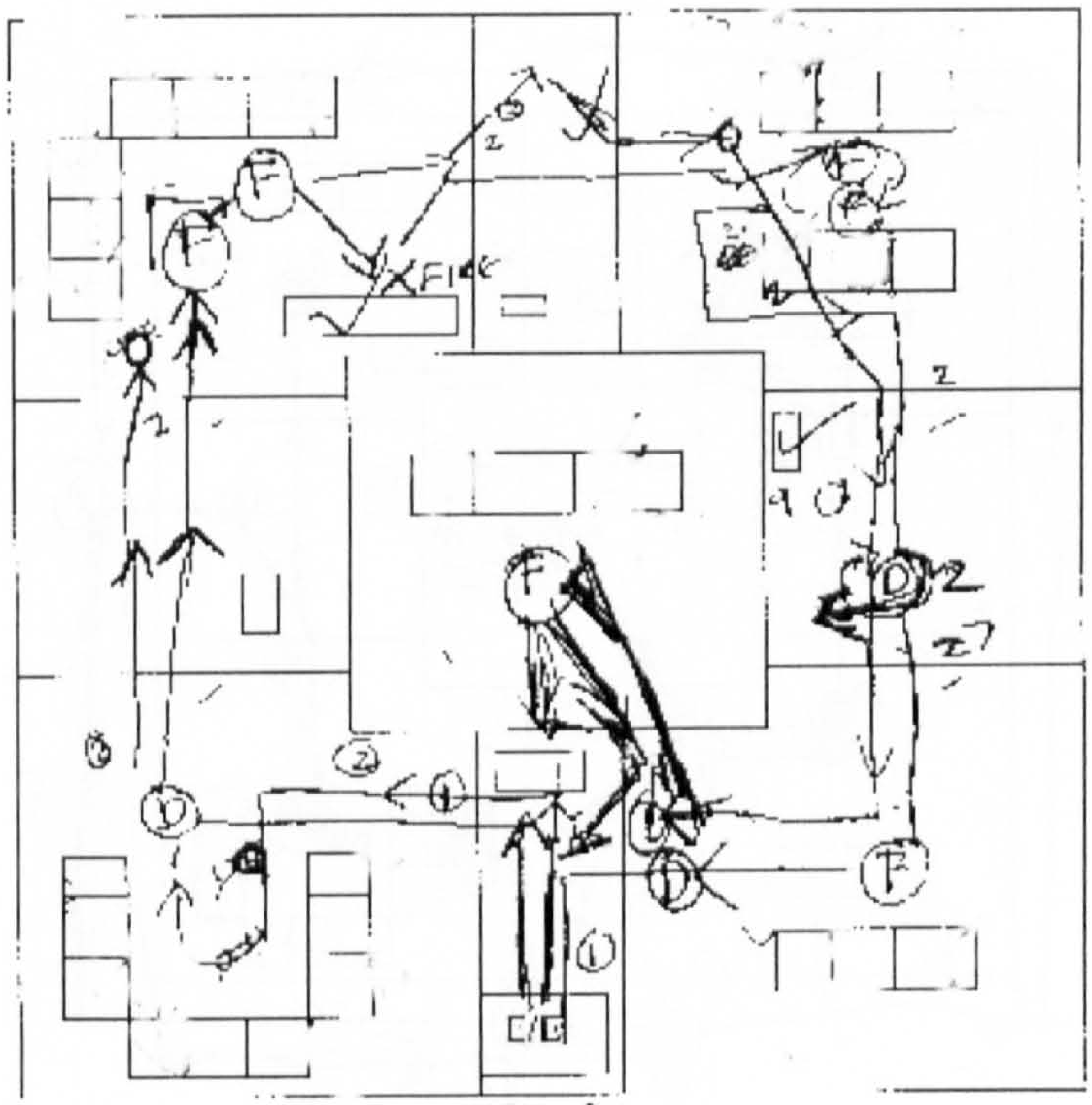

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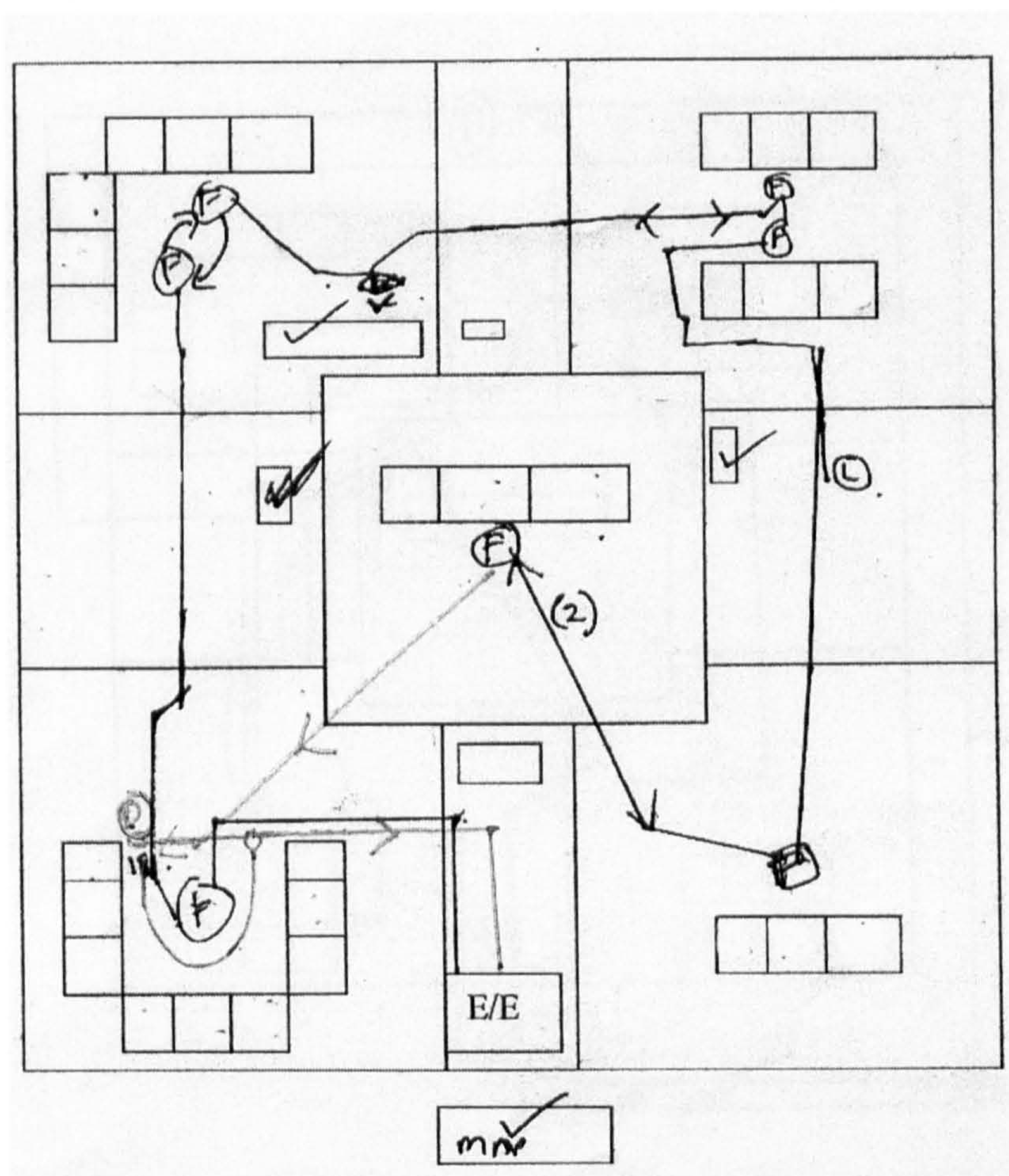

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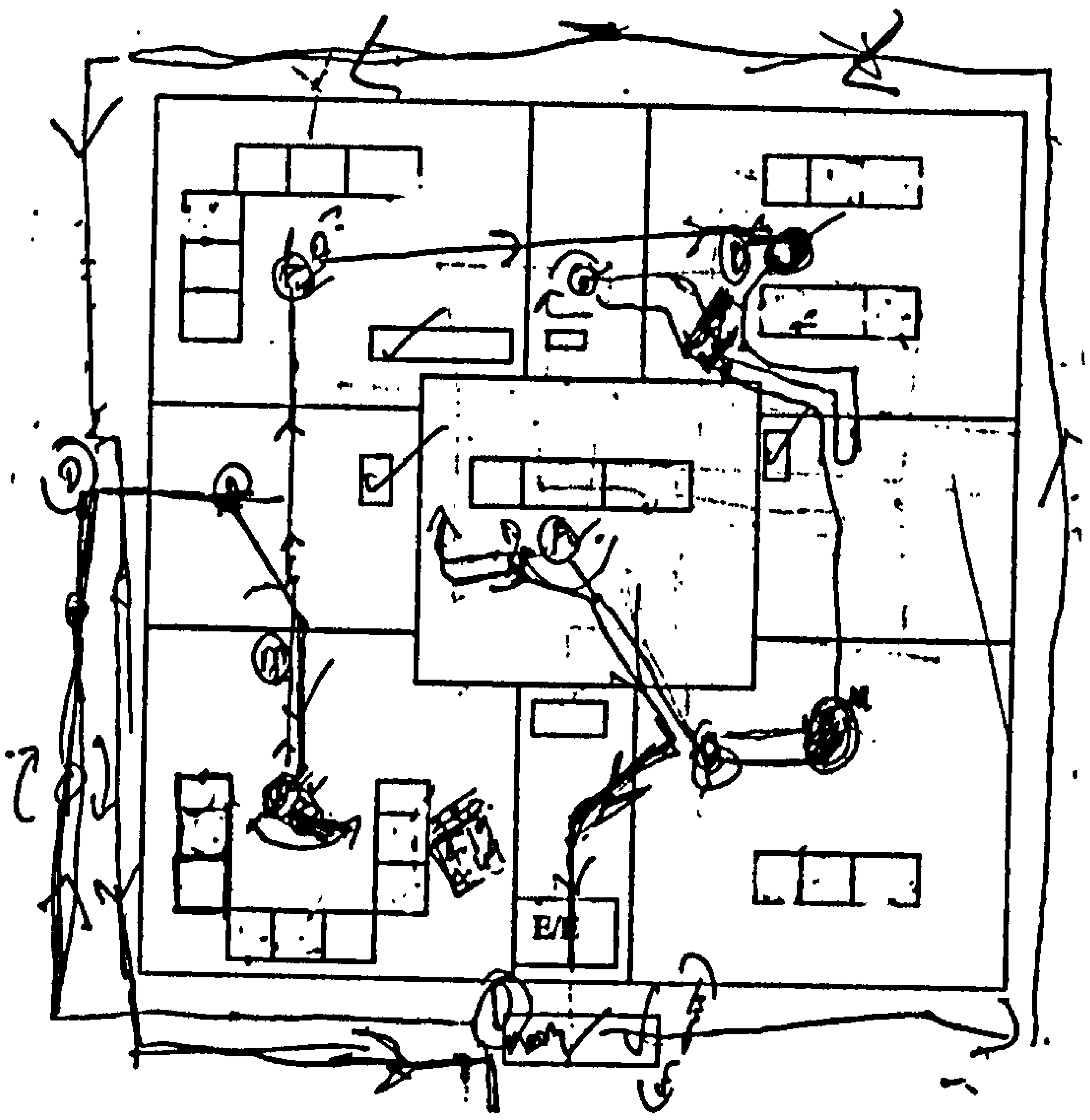
Journey Maps—Exporation



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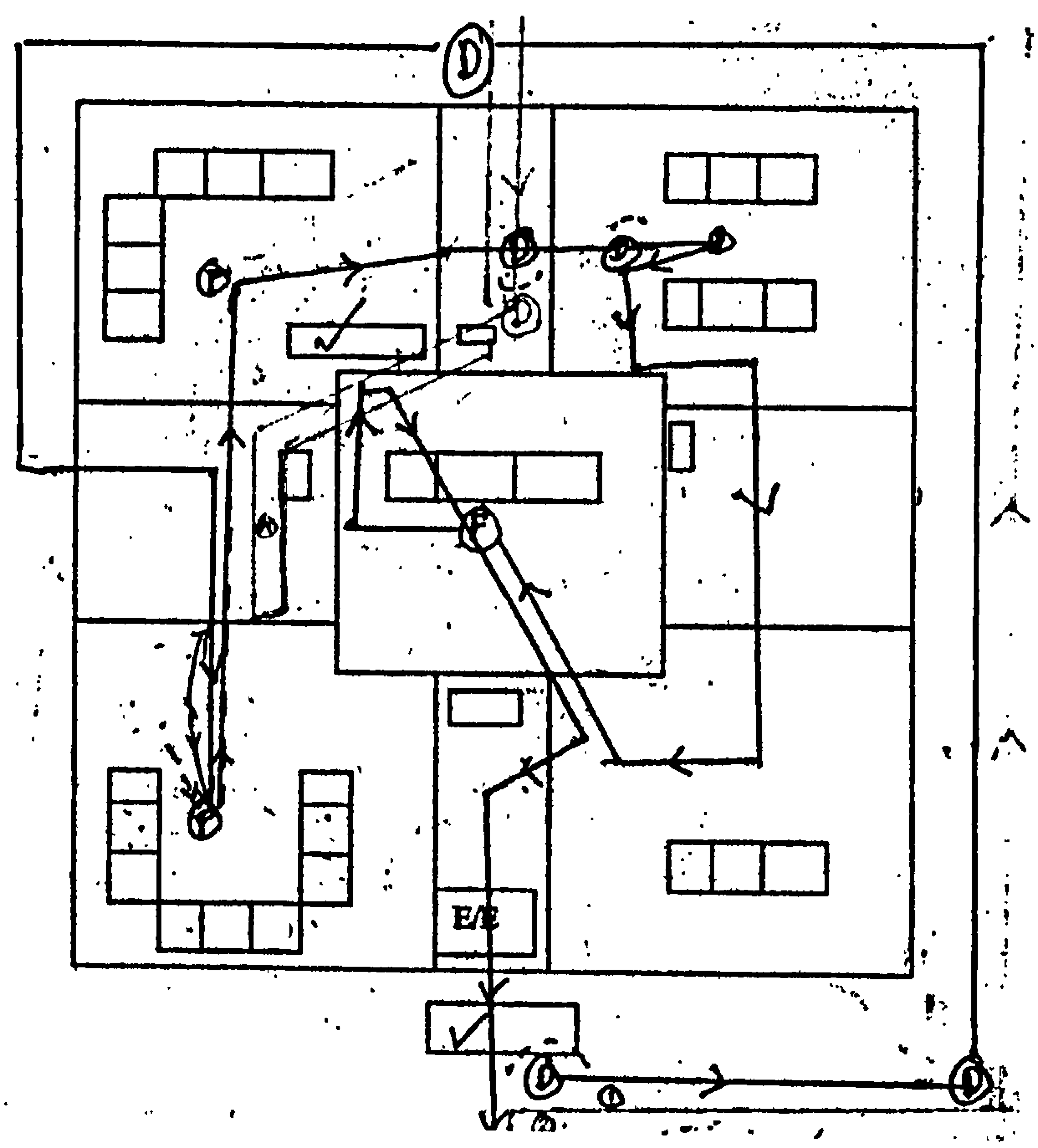

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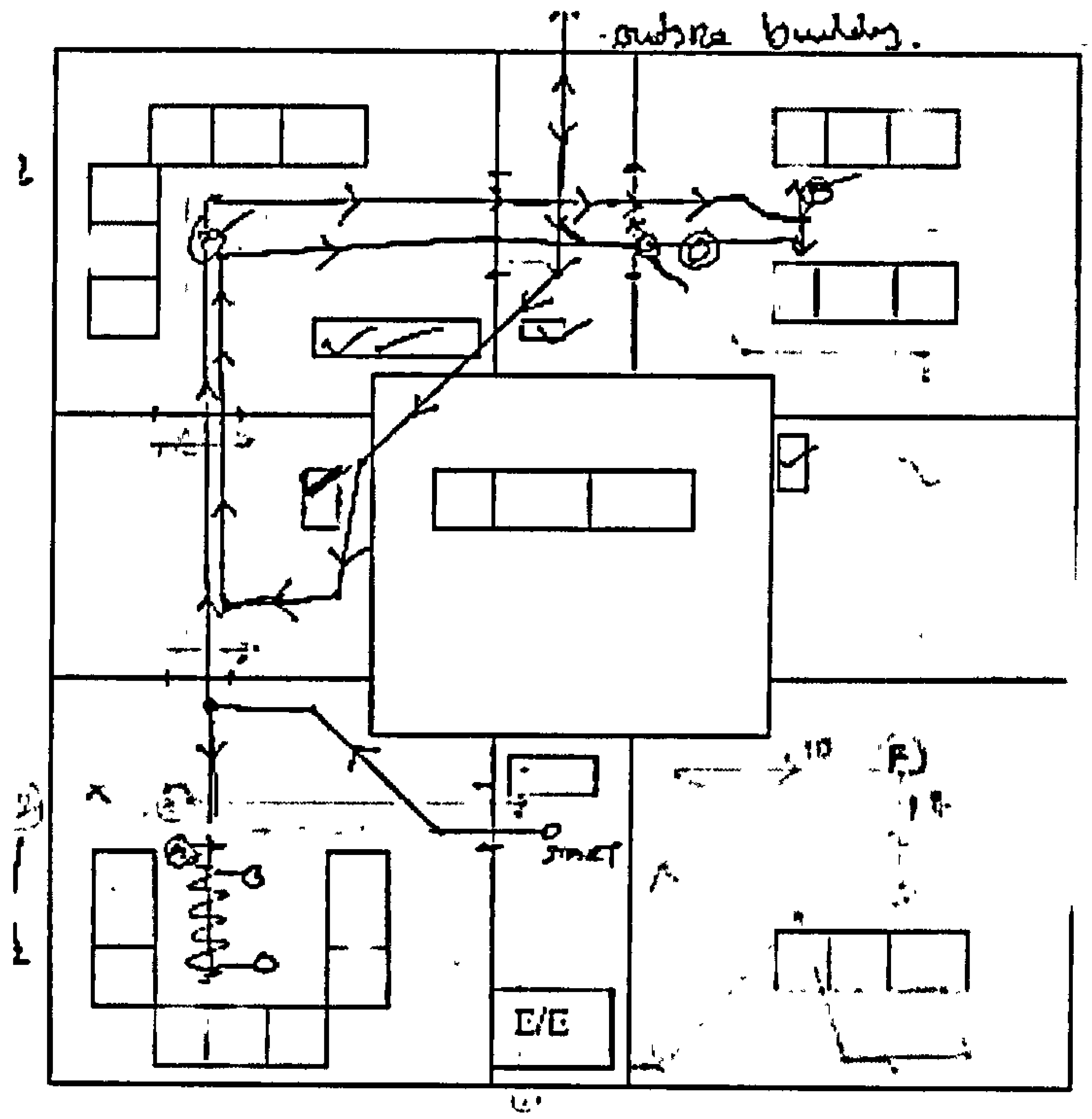
Journey Maps—Exploration



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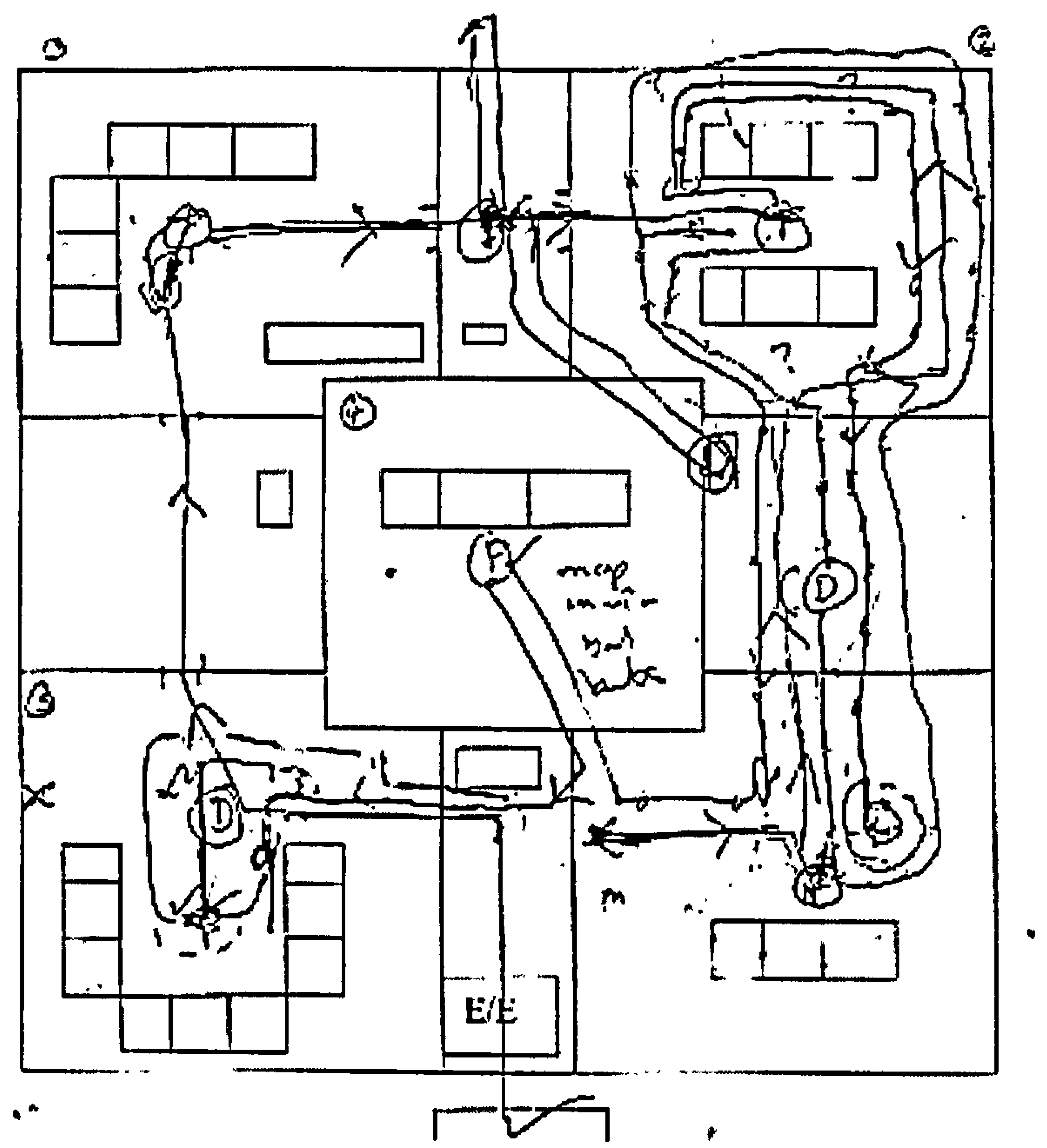

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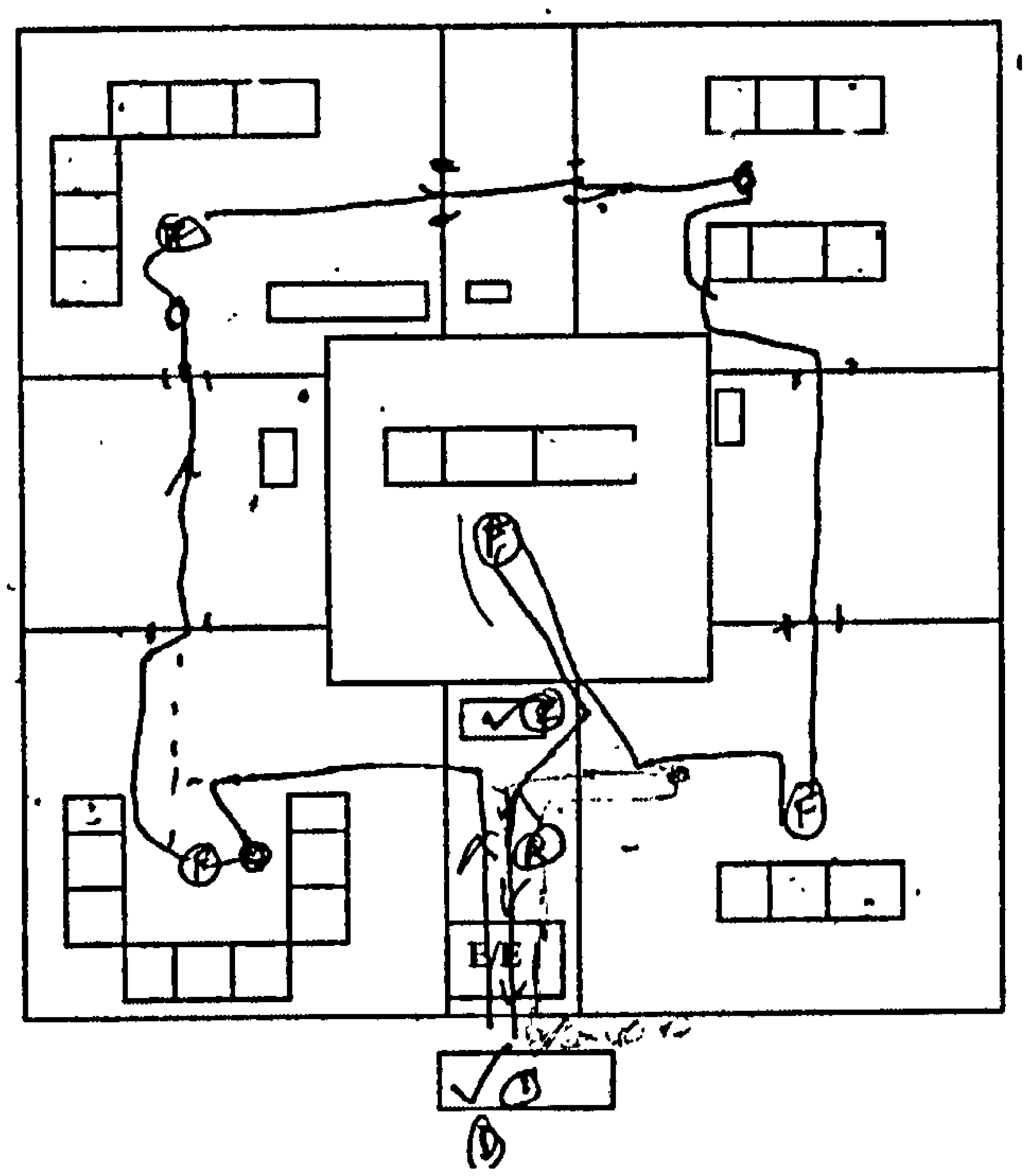
Journey Maps—Exploration



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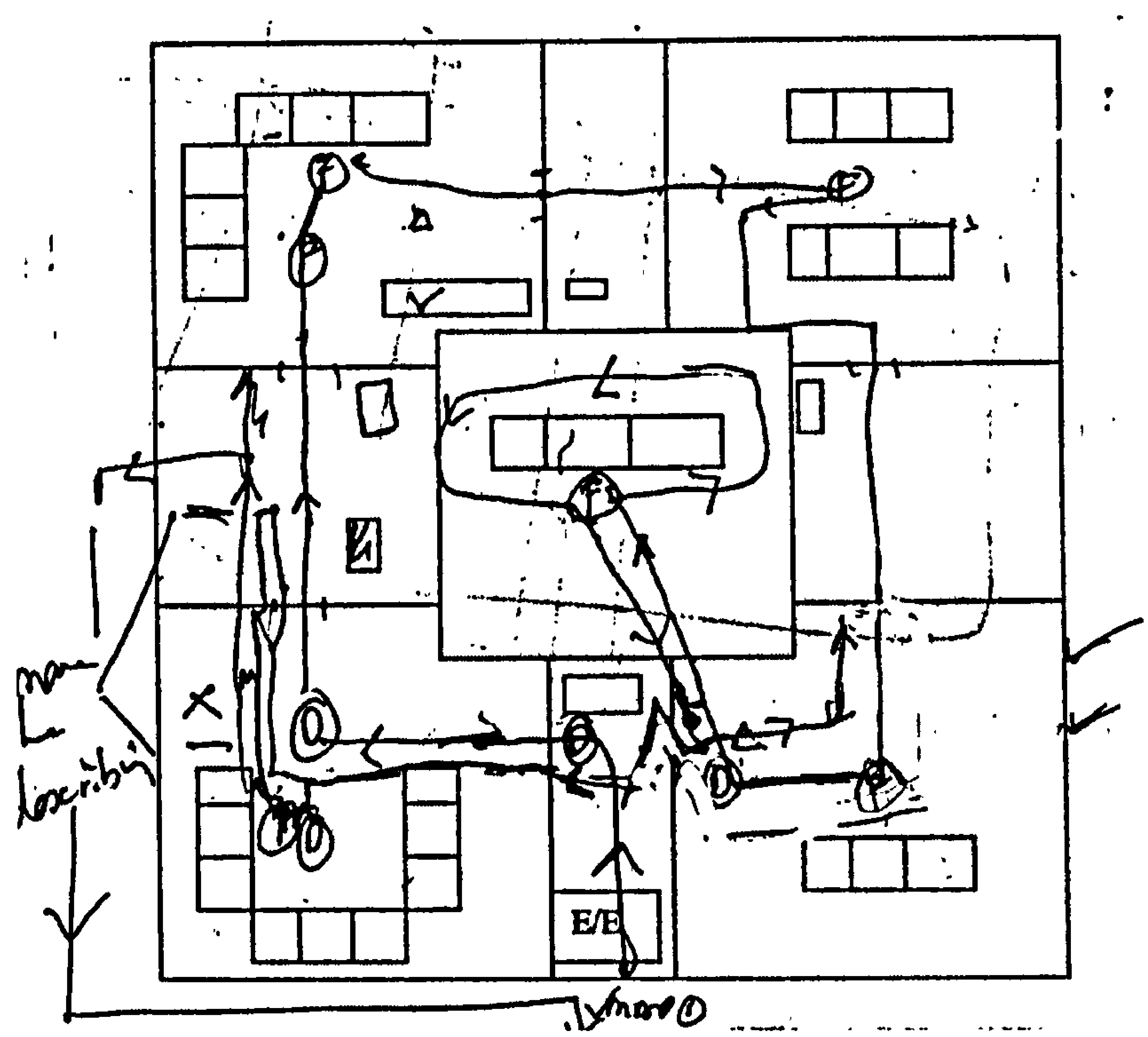

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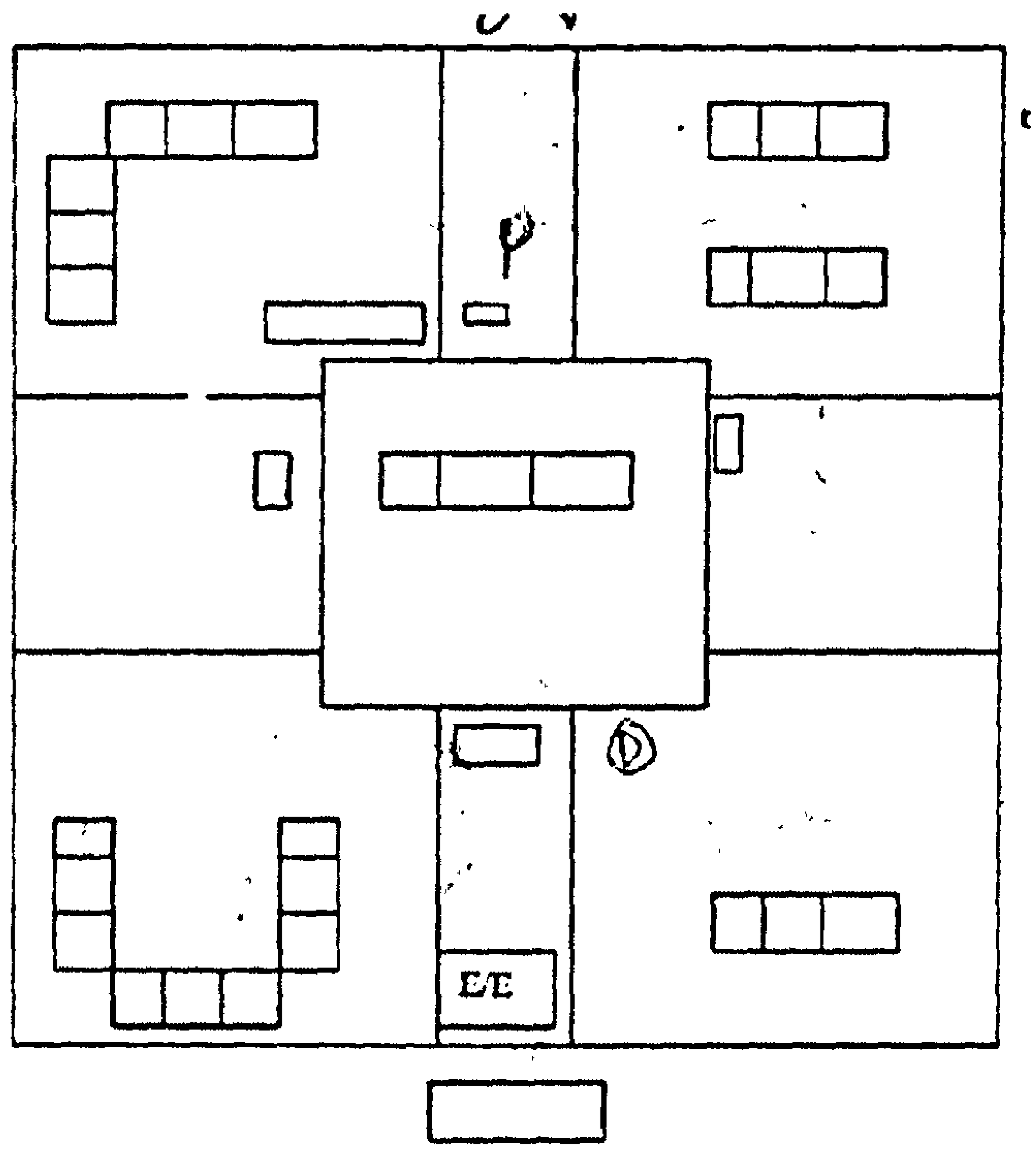
Journey Maps—Exploration



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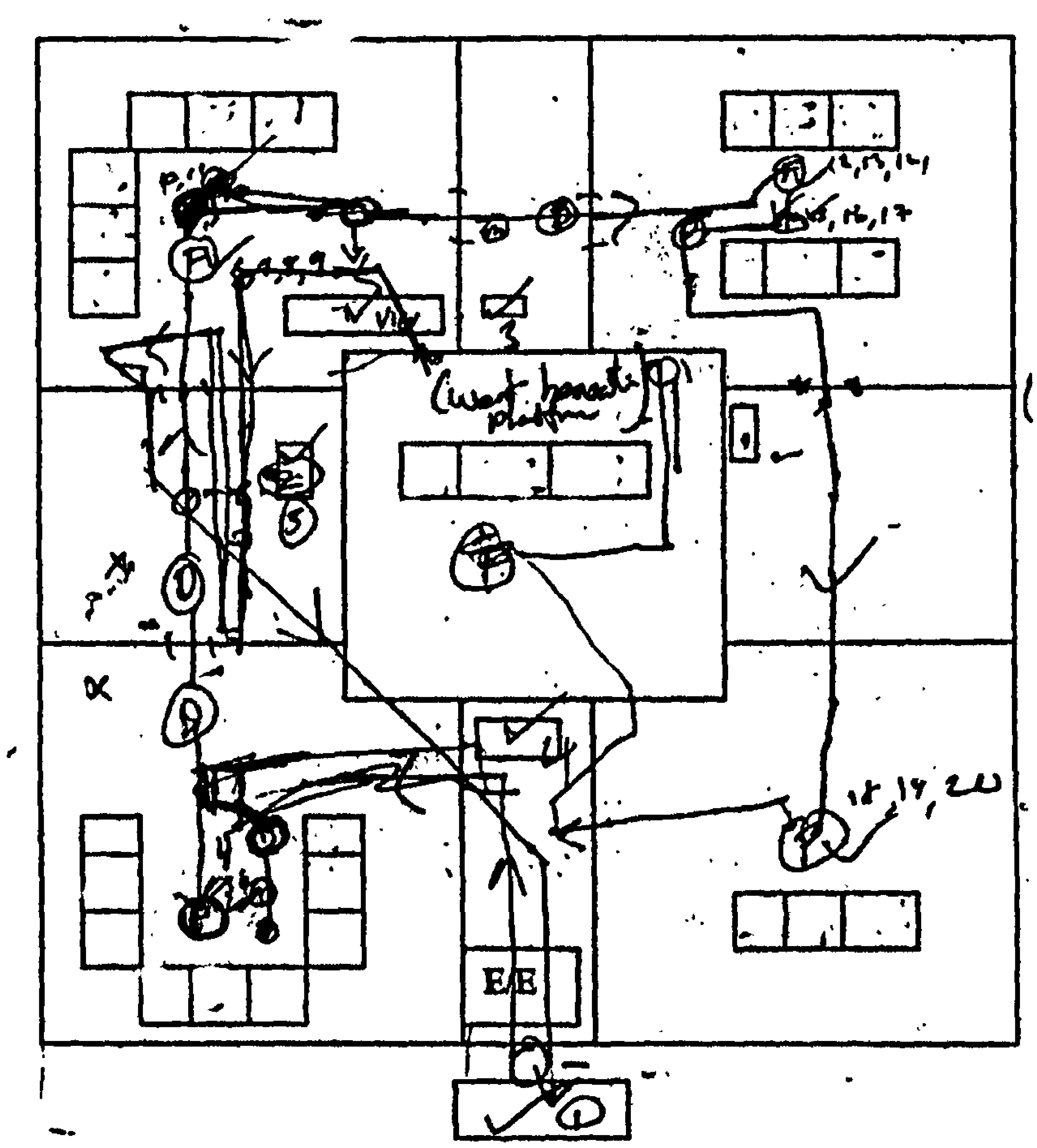

H

A Study of Digital Learning Environments

Parts of this study

I Scenario presentation
II Problem solving
III Tasks
IV Questions

Study Environment 1

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HCI Group, School of Computing, Napier University, Edinburgh, EH14 1DJ

I. Scenario Description

Imagine that you come to work one day and Sarah, a person in your work team is sick. Now you have to be her stand-in at a meeting later today. **She has written a note for you:**

> Can you give a brief presentation of schematic modeling? You only need to say a few words about it at the meeting with the bord of advisors later today. See the electronic exhibition ..

II. Problem solving

You need to go to the exhibition Sarah is refering to and find out as much as you can about "schematic modeling". Your assistant will guide you there. Sarah has asked you to explore the electronic exhibition for her, however she would also like you to take some notes.
"I'd be grateful if you would write down the names of the patterns you see in the order that you encounter them."

Once you are finished in the exhibition please go to the exit.

III. Questions

Choose the best option from your viewpoint

1. It is easy to understand how the information is organized within the exhibition

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

2. To learn from the exhibition is easy

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

3. The exhibition is engaging

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

4. The content of the exhibition is comprehensible

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

5. The exhibition stimulates thinking

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

6. I don't feel tired at all

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

7. The exhibition is sterile

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

8. The maps helped me find my way around

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

9. The maps helped me to gain an overview of the exibition

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

10. The floor colours helped me identify different areas of the exhibition

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

11. On arriving in the exhibition I was able to comprehend the size of it

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

12. The paths made it easy for me to find my way around

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

13. The paths reflected where I wanted to go

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

14. The signs helped me identify areas of the exhibition

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

15. The signs reflected where I wanted to go

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

16. The paths made it clear when I was entering and leaving parts of the exhibition

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

17. The signs made it clear when I was entering and leaving parts of the exhibition

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

18. I felt overwhelmed by the amount of information presented

to me

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

19. I did not feel lost within the exhibition

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

IV. Tasks

PLEASE DO NOT REFER TO ANY PREVIOUS ANWERS OR USE THE MAPS PROVIDED WITHIN THE WORLD.

PLEASE ASK FOR THE TASK CARD PRIOR TO ANSWERING THE QUESTIONS ON THE FOLLOWING PAGE.

20. The paths made it easy for me to find my way around

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

21. The paths reflected where I wanted to go

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

22. The signs helped me identify areas of the exhibition

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

23. The signs reflected where I wanted to go

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

24. The paths made it clear when I was entering and leaving parts of the exhibition

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

25. The signs made it clear when I was entering and leaving parts of the exhibition

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

26. I did not feel lost within the exhibition

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

Answer briefly the following questions

1. What did you not like about the exhibition?

2. What did you like about the exhibition

3. What difficulties did you encounter?

4. What is your opionion of the estethics of the exhibition?

5. Characterize the exhibition in your own terms

Please diagram the exhibition in the space provided below

Background information

Age

____

Sex

female ☐ **male** ☐

Educational level

gymnasium ☐ **university** ☐ **graduate** ☐

Which style of architecture do you prefer?

Victorian ☐ **Functionalist** ☐ **Modern** ☐

How much experience do you have with computer games?

none ☐ **a little** ☐ **I play weekly** ☐ **I play daily** ☐

If you have experience with computer games, which kind do you prefer?

action ☐ **adventure** ☐ **strategy** ☐

A Study of Digital Learning Environments

Parts of this study

I Scenario presentation
II Problem solving
III Tasks
IV Questions

Study Environment 2

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I. Scenario Description

Imagine that you come to work one day and Sarah, a person in your work team is sick. Now you have to be her stand-in at a meeting later today. **She has written a note for you:**

> Can you give a brief presentation of schematic modeling? You only need to say a few words about it at the meeting with the bord of advisors later today. See the electronic exhibition ..

II. Problem solving

You need to go to the exhibition Sarah is refering to and find out as much as you can about "schematic modeling". Your assistant will guide you there. Sarah has asked you to explore the electronic exhibition for her, however she would also like you to take some notes.
"I'd be grateful if you would write down the names of the patterns you see in the order that you encounter them."

III. Questions

Choose the best option from your viewpoint

1. It is easy to understand how the information is organized within the exhibition

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

2. To learn from the exhibition is easy

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

3. The exhibition is engaging

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

4. The content of the exhibition is comprehensible

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

5. The exhibition stimulates thinking

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

6. I don't feel tired at all

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

7. The exhibition is sterile

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

8. The paths made it easy for me to find my way around

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

9. The paths reflected where I wanted to go

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

10. I felt overwhelmed by the amount of information presented to me

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

11. I did not feel lost within the exhibition

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

12. On arriving in the exhibition I was able to comprehend the size of it

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

IV. Tasks

PLEASE DO NOT REFER TO ANY PREVIOUS ANWERS .

PLEASE ASK FOR THE TASK CARD PRIOR TO ANSWERING THE QUESTIONS ON THE FOLLOWING PAGE.

14 The paths made it easy for me to find my way around

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

15. The paths reflected where I wanted to go

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

16. I did not feel lost within the exhibition

strongly agree	agree	no opinion	disagree	strongly disagree
☐	☐	☐	☐	☐

Please diagram the exhibition in the space provided below

Answer briefly the following questions

1. What did you not like about the exhibition?

2. What did you like about the exhibition

3. What difficulties did you encounter?

4. What is your opionion of the estethics of the exhibition?

5. Characterize the exhibition in your own terms

Background information

Age

____

Sex

female	male
☐	☐

Educational level

gymnasium	university	graduate
☐	☐	☐

Which style of architecture do you prefer?

Victorian	Functionalist	Modern
☐	☐	☐

How much experience do you have with computer games?

none	a little	I play weekly	I play daily
☐	☐	☐	☐

If you have experience with computer games, which kind do you prefer?

action	adventure	strategy
☐	☐	☐

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