

UNIVERSITY OF LEICESTER

The Role of Individual Differences and Metaphor in Hypermedia Navigation

by
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Declaration of Authorship

I, KINE DORUM, declare that this thesis titled, 'PROCESS AND STRUCTURE: THE ROLE OF NAVIGATION AND METAPHOR IN HYPERTEXT ENVIRONMENTS' and the work presented in it are my own. I confirm that:

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- Where I have consulted the published work of others, this is always clearly attributed.
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Abstract

Research and practice within interaction design are often based on the assumption that computer interfaces are understood through metaphorical reasoning, in that they communicate abstract information by depicting) a concrete object or situation from which the abstractions can be inferred. Within hypertext systems, metaphors are used to assist in navigating, or locating information, by providing a familiar frame of reference.

This research is concerned with the psychological processes underlying the utilisation of interface metaphors. It aims to examine the value of prior knowledge and spatial properties of metaphor source domains in supporting hypertext navigation tasks, and how these relate to task and user characteristics. These issues are investigated through a series of eight studies. The first three studies examine constructs and measurements of individual differences (cognitive style, experience, confidence, and visuospatial ability). The remaining ones are experiments measuring the direct effects metaphor spatiality and familiarity, and interactions between metaphor and: task phase (search and retrieval); hyperlink structure; and exposure type (active and passive). Performance and behaviour is measured in terms of length and structure of navigation patterns, accuracy of mental representations, and self-reported disorientation. The experimental tasks are carried out using simple hypertext structures representing the different metaphors.

The results show that type of metaphor does affect performance and behaviour on a general level. It is found that the familiarity of a metaphor source domain is of great importance for users' ability to form mental representations of a hypertext structure. Furthermore, the influence of metaphor is greatest when it is based on a prototypical domain. The influence of metaphor on performance and behaviour is stronger than that of individual differences among users.

From a theoretical point of view, the findings indicate that the extent to which users benefit from interface metaphors is predominantly based on top-down processing. Users are relying more on schematic representations of prior knowledge than on immediate perceptual information. From a practical point of view, this research implies that fewer geometric or spatial constraints may be applied when choosing appropriate source domains for

interface metaphors. It also suggests that when provided with a familiar source domain, individual cognitive abilities are of less importance than what has been proposed within previous user-centred design literature.

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Chapter 1

1 Lost and Confused

1.1. Why Study Hypertext Navigation?

Hypertext environments such as the Internet and the World Wide Web¹ have a unique feature compared to traditional media (e.g. books) in that they allow users to choose their own routes through the information space, not only along a linear axis, but also for example up, down and across information hierarchies. In this sense, hypertext is more comparable to a library than a single book. Hypertext navigation is a widely investigated area, and one of the reasons is that hypertext systems are rich and complex sources of information offering many possibilities for learning and information sharing, while on the other hand, this very feature can lead to potential problems

¹ The two terms are often used interchangeably. To be precise, however, the Internet refers to an interconnection of computer networks, whereas the World Wide Web refers to a subset of the Internet (a collection of linked documents)

for both users and information providers. If a structure is difficult to navigate, users can become frustrated and move on without finding the data they were looking for, which in turn means the hypertext system has failed in delivering information (e.g. Ahuja & Webster, 2001; George Saade & Alexandre Otrakji, 2004; Lawless & Kulikowich, 1996).

The problem with lost and confused hypertext users was identified as far back as the 1980s (Conklin, 1987), and it has persisted ever since the Internet became available to the everyday personal computer user in the 1990s. The phenomenon has become known as 'lost in hyperspace' (Edwards & Hardman, 1989). Not knowing where you are, where you came from, or how to get to where you want to go is a frustrating situation for the user, and it can also have a negative effect on performance; users may not be able to find information efficiently, or fail to find it altogether. Cognitive effort spent orienting to the content and structure of a hypertext system generally occurs at the expense of the elaborative and evaluative processing of the information contents (e.g. Eveland & Dunwoody, 2000), and results in an inaccurate or poor mental model of the system. A mental model is often referred to as a conceptual representation within a

person's mind that is used to help the person understand the world and to help the person interact with the world (e.g. Williams, Hollan, & Stevens, 1983). A hypertext environment that is failing to fulfil its purpose is a problem not only for the user who cannot perform whatever task they set out to do, but also for the designers and those delivering the material.

With the growth of hypertext and hypermedia environments, such as the Web and hypertext-based learning material, designers face the constant challenge of developing applications that meet diverse user needs (Serrano, Maguitman, Boguñá, Fortunato, & Vespignani, 2007). Today's user population is large and heterogeneous; therefore interfaces intended for use by non-specialists cannot be designed with a homogenous set of 'ideal' users in mind. In order to develop effective interfaces, dimensions of the individual user have to be taken into account (e.g. Allen, 2000; Dillon & Watson, 1996). Individual differences are increasingly seen as important issues, rather than just 'noise' in performance data, as reflected in the substantial number of existing studies in the area (e.g. Marangunić & Granić, 2009).

The overarching goal of this thesis is to consolidate and identify some of the main issues and approaches to investigating

hypertext navigation and disorientation and to evaluate the evidence for these. One of the main problems within 'lost in hyperspace' and navigation research is the lack of consistency in the type of metrics used. Within the literature, quantification of navigation performance typically focuses on efficiency in terms of number of steps taken to perform a task, often referred to as path length (e.g. Otter & Johnson, 2000; Smith, 1996), time on task (e.g. Gwizdka & Spence, 2007), or choice of navigation tools (back button, menu items etc.) (Ahmed & Blustein, 2006).

The general approach to researching hypertext navigation is dominated by experimental designs comparing different navigation tools or structural characteristics of the material (e.g. layout), and focuses less on understanding the psychological theories underlying the behaviour and performance outcomes. Studies that have examined the influence of individual differences are often focusing on one particular factor (e.g. spatial ability), operationalised in one particular way, and as such fail to provide a fuller more integrated, understanding of the psychology of navigation. The present research aims to provide a more integrated view of aspects of hypertext navigation. The focus is on four main issues: the physical structure of a hypertext

environment (e.g. hyperlink menu layout); the metaphor in which the hypertext is embedded; user's mental representation of the structure (i.e. how they represent the environment before their 'mind's eye'); and the role of some key individual differences that can potentially shape navigation behaviour, namely cognitive style, visuospatial ability, and experience.

1.1.1. Overview of the Thesis

Chapter 2 is broadly divided into three sections. The first section reviews theories that have been proposed to describe navigation in real-world and computer-based environment. The second section reviews theories concerning metaphor, both as a general concept and as used in interface design. It then considers how interface metaphors can be used as cognitive tools to aid navigation. The third section reviews the role of individual differences, and how these may influence navigation and the effect of interface metaphor in computer user performance and behaviour.

Chapter 3 presents the results of three studies investigating the reliability and validity of cognitive processing style, and different conceptualisations and measures of experience. The chapter also considers the literature on computer

navigation in more depth, and describes a preliminary study examining cognitive style and navigation paths in a typical hypertext environment. The study also establishes the type of measures to be used for quantifying navigation performance in subsequent experiments.

Chapter 4 discusses the spatial aspects of hypertext systems and includes an in-depth description of the literature on metaphors in interface design. The chapter also presents theories of spatial cognition and the development of spatial knowledge, and moves on to describe how individuals form internal representations of real-world and hypertext environments and how these may be measured. The chapter concludes with a study examining the relationship between cognitive style and spatial ability.

Chapter 5 describes a series of three studies examining the effects of a set of interface metaphors (spatial/familiar, spatial/non-familiar, non-spatial/non-familiar) on navigation and internal representation, and also how metaphor interacts with website structure and type of task (search and retrieval). The possible influence of individual differences is also measured. Findings show a strong effect of type of metaphor in that the

spatial/familiar metaphor produces superior performance and accuracy. Furthermore, the effect of metaphor largely overrides that of website structure and task type.

Chapter 6 further explores the familiarity of metaphors, and investigates the degree whether performance and accuracy can be attributed to the spatial properties of a metaphor or the familiarity aspect. The nature of familiarity is discussed in light of prototypicality and prior exposure.

Chapter 7 comprises a general discussion of the findings, conclusions that can be drawn, and theoretical and practical implications. It also contains a brief section of possible avenues for future research.

Chapter 2

2 The Navigation Experience

2.1. Introduction to Topics

A term that originally referred to seafaring and the navigation of ships and boats, navigation now also extends to navigation on land and in space, and more generally to the activity of finding one's way through an environment. This chapter reviews previous research that has investigated navigation in electronic information spaces and the use of metaphor as a tool to aid user performance. Aristotle (s.a.) defined metaphor as 'the application of an alien name by transference' more loosely translated, calling something by another name. Many of the findings that have been made within navigation and metaphor research can be interpreted more clearly if certain psychological characteristics of the users are taken into account. Research into metaphor has to a large extent

focused on metaphor for aiding spatial orientation or simply as a mnemonic device, not as a means to aid navigation. The chapter is divided accordingly. After brief definitions of navigation and metaphor as areas of psychological research, the main part of the review considers how each can be studied with relevance to navigation behaviour and performance. The section that discusses navigation considers how theories of navigation in real-world spaces have been applied to navigation in electronic spaces. Two specific areas are addressed that have been studied in greater detail: mental models and disorientation. The section that discusses metaphor as a cognitive tool concentrates on previous research in interaction design that has motivated this research. The final section of the literature review presents four areas that are of potential importance in studying navigation and metaphor: cognitive processing style, prior knowledge and experience, and visuospatial ability.

2.1.1. Navigation: Moving Through an Environment

Navigation has been a key issue within hypertext research for more than a decade, with researchers studying the theme within a variety of subject areas, such as education, psychology, and usability. With the development of large information spaces

such as hypertext structures, gaining an understanding of user navigation has become an important issue for information search delivery (e.g. Benyon & Höök, 1997). Therefore, the primary factors to consider are the origins and approaches to navigation within electronic information spaces. A general definition of navigation can be found in Montello (2005):

“Navigation is coordinated and goal-directed movement through the environment by organisms or intelligent machines. It involves both planning and execution of movements”. (p. 257)

Ontology of Terms

This section provides a brief introduction to the terms commonly used within hypertext research. The hypertext field uses the concept of the ‘node’ for a page or piece of information in a hypertext system. Nodes are interlinked using ‘links’. Links lead from a ‘link anchor’ in one node to a ‘link destination’, either located in another node or in a different part of the same node. In textual environments, link anchors are typically made visible by underlining a word or by using a symbol. This visible form sometimes gives information on the nature of the link destination. A ‘path’ is a sequence of nodes and links the user follows to reach a certain node. Some researchers (e.g. Dieberger, 1994b) have adopted the term ‘landmark’ referring to well-

known, easily recognised nodes (e.g. index pages or tables of contents). Landmark nodes are intended to help with orientation and provide helpful information. The terms used within hypertext navigation have a strong affinity with architectural terms, for example as defined in the seminal work by Lynch (1960) describing navigation within cityscapes. He termed the mental representation of an environment the 'environmental image'. This image consists of five elements: node, path, edge, district and landmark. Edges refer to perceived borders within an environment; districts refer to areas with characteristic commonalities (e.g. building style).

Research Perspectives

A popular approach to hypertext navigation is based on the idea that there are similarities between navigation in the physical world (real-world navigation) and information seeking in electronic environments (e.g. Canter, Rivers, & Storrs, 1985; Dahlbäck, 2003; Kim & Hirtle, 1995) both as a task and as a general activity. The architect Passini (1992), who used the term wayfinding synonymously with navigation, defined it as the cognitive and behavioural ability to reach spatial destinations. This conception is based on Downs and Stea's (1977) theory of

wayfinding as composed of four steps: orienting oneself in the environment, choosing the correct route, monitoring this route, and recognising that the destination has been reached. In the context of hypertext systems, the concept of 'navigation' in this context is in itself a metaphor. Based on the original meaning of the term, hypertext navigation refers to the activity of 'steering a course' by moving between nodes (Norman, 1994). Dillon, Richardson and McKnight (1993) claimed this metaphor is useful because it enables people to visualise a semantic space (e.g. a hypertext system) by giving it a physical representation. Following this line of thought, research results on real-world navigation (e.g. within the fields of geography and architecture) should be possible to apply to electronic navigation.

The real-world analogy has prompted the use of spatial metaphors to describe information-seeking in hypertext systems (e.g. Ahmed & Blustein, 2006; Downing, Moore, & Brown, 2005; Kim & Hirtle, 1995; Kuhn & Blumenthal, 1996). Kim and Hirtle identified a set of analogous tasks, including route planning and execution, and coordinating navigation and information. According to Elm and Woods (1985), the relative success of these tasks relies on:

1. "The ability to generate specific routes as task demands require"
2. "The ability to traverse or generate new routes as skilfully as familiar ones"
3. "Orientation abilities, that is, the development of a concept of 'here' in relation to 'other places'" (p. 927)

Developing Spatial Knowledge in Real-World Environments

Current theoretical frameworks for explaining spatial knowledge acquisition and representation in large-scale spaces are either a sequence of stages or continuous. The Landmark, Route, Survey (LSR) model proposed by Siegel and White (1975) is one of the longest standing models of what is known as 'spatial microgenesis'. It consists of three stages: recognition of landmarks (to provide orientation), route knowledge (directions from a person-centred frame of reference), and survey knowledge (requiring a world-centred frame of reference). Landmark knowledge is acquired first and is based on features of the environment that are relatively stable and conspicuous. This is followed by the development of route knowledge. At this stage we can find the way between two points by drawing on landmarks to make decisions about directions (e.g. when to turn

left/right). The final stage is survey knowledge. At this stage we know the general direction of places and are able to plan generate new routes. In terms of performance, this model suggests that efficiency and accuracy increase with each successive stage.

Based on the observation that in some cases, lengthy exposure to an environment does result in survey knowledge, whereas in other cases survey knowledge is developed almost immediately, Montello (1998) proposed an alternative, continuous framework. Rather than developing in discrete stages, Montello suggested spatial knowledge is acquired continuously. This enables individuals to perform tasks such as taking shortcuts without having first acquired landmark and route knowledge, as would have been necessary following Siegel and White's (1975) stage framework. Similarly, Colle and Reid (1998) proposed a dual mode model, claiming that the development of survey knowledge does not necessarily have to be preceded by landmark and route knowledge. Termed 'the room effect', the dual mode model suggests that survey knowledge can be acquired quickly for local regions and more slowly for remote regions. The spatial relationships described in these models can be translated to the conceptual relationships found in a hypertext

system. Salient nodes (e.g. 'index'/'home' pages) can function as landmarks; route knowledge refers to the sequence of nodes to a specific target; and survey knowledge refers to the relative position and distance between nodes. These three types of spatial knowledge require the development of representations of the environment in long-term memory, a process necessary in both real-world and hypertext navigation (Dias & Sousa, 1997).

There is also an approach to studying navigation that can be considered to have originated from field theory. Field theory in essence states that behaviour is determined by the totality of an individual situation (Marrow, 1969). According to this perspective, people are immersed in an information environment that continuously changes value with every movement and over time. The environment, coupled with a person's intentions, can explain their navigation through the environment (Gibson & Crooks, 1982; Gibson, 1986). Gibson and Crooks studied car driving, describing it as 'a type of locomotion through a 'terrain' or field of space' (p. 120). The path of the car is determined not only by the driver's intentions, but also the physical constraints of the environment and the action capabilities of the person-and-car system (e.g. braking distance). The system idea is interesting

in the context of the present research, as a reference to interface between user and hypertext system. The act of traversing hypertext nodes is not influenced solely by the user and their intentions, but also by the constraints and possibilities of the hypertext. Within the framework of ecological interface, design what is displayed on-screen is a mediating form, between the user and the information (e.g. Torenvliet, Jamieson, & Vicente, 2000; Vicente & Williges, 1988). Allowing the user to interact directly with the 'raw' information is not practical, therefore the information needs to be shaped in a way that gives 'sense' to and guides the interaction, for example allowing for purposeful navigation.

Another field-theoretic perspective is the concept of location-specific patterns of visibility, known as isovists (Benedikt, 1979; Kadar, Flascher, & Shaw, 1995; Kadar & Shaw, 2000). As an observer moves through an environment, the visual information changes continuously. At each vantage point in space, an isovist can be defined, and the emerging pattern of isovists serves to inform navigation. The concept of isovists is relevant to the hypertext navigation situation. The screen presents a limited view of the overall hypertext structure,

showing one portion at a time while occluding other. This is what Woods, Roth, Stubler, and Mumaw (1990) referred to as the 'keyhole effect'.

Real-World and Hypertext: Important Distinctions

Although the navigation metaphor has been accepted and integrated into the everyday computer language, there is some disagreement as to whether the term is applicable to electronic navigation. Dahlbäck (2003) challenged the use of navigation as a metaphor, or analogy as he called it. In Dahlbäck's view, the activities and spaces are fundamentally different, thus there is no clear connection or evidence that electronic navigation draws on the same cognitive resources as real-world navigation. One of the main arguments underlying this view is that the array of sensory information is far greater in real-world navigation, where the individual can make use of for example vestibular cues in their navigation (e.g. Yong, Paige, & Seidman, 2007). In electronic navigation (at least in the case of two-dimensional displays) the individual mainly relies on visual cues. Another observation supporting this argument is the arbitrary nature of hypertext spaces; they lack the stable and permanent spatial relationships

of the real world. The problem with the plasticity of electronic spaces was first identified by Wittenburg (1997):

“The concept of navigation in cyberspace has a completely different physics from navigation in the physical world. The cartographers and engineers of cyberspace must not only create the maps and the instruments but also the world itself”. (p. 1)

In other words, the navigability of a hypertext system is not only due to characteristics of the system in itself, but also the designers and developers who give it shape. Another interesting point is what Dieberger (1995) called ‘magic features’. In hypertext systems, as opposed to real-world environments, a person can take shortcuts between nodes, skipping unnecessary steps. For example, in a node hierarchy, or ‘tree’, a user can go straight from the top level to the bottom without having to visit the intermediate levels. This distorts the perception of space and distance, and is at odds with the physical constraints of the real world. Dieberger likens this to walking through a magic door. Ruddle, Howes, Payne and Jones (1998) drew parallels between following hyperlinks and travelling on underground railways. It requires little effort in terms of locomotion, and the spatial experience is limited to the tunnel walls, which provide few spatial cues. In order to orient themselves in space, travellers

have to refer to maps (e.g. Montello, 2005). In short, what happens during navigation is that we recognise features in our immediate surroundings, which we use to key our current location to our locations on a map. This map can be either internal (cognitive) or external (cartographic). The map is then 'read' to determine a route to a desired destination.

Marcus (2002) defined electronic navigation as "movement through mental models afforded by windows, menus, dialogue areas, control panels, etc." (p. 48), which on the surface sounds quite different and far more limited than Downs and Stea's (1977) and Montello's (2005) general definitions of navigation. However, there is one common aspect: the idea of movement. The fact that there is a difference between locomotion, or moving around in the physical world, and 'moving around' sitting in front of a computer screen is indisputable; but regardless of the nature of the movement, with a sequence of content accessed by the person navigating.

2.1.2. Mental Representation, Mental Models and Cognitive Maps: Conceptual Confusion

How do people conceive of an information space? The concept of mental representations is crucial to the understanding of how users experience information environments. Research on

mental representations of text structure focuses on how representations can develop, what form they may take, and potential effects on an individual's performance in terms of information processing. Within cognitive psychology and interaction research, this area is dominated by three theoretical concepts: mental models, schema theory, and strategic discourse processing.

Glenn and Chignell (1992) provided a review of the psychological factors that may be implicated in navigation, particularly in the navigation of hierarchical structures such as hypertexts, among these mental models. The understanding that users have of an information space, their mental representation, affects their ability to navigate through it quickly and efficiently. From one point of view, a users' mental representation can direct the navigation; but viewed from a different angle, an interface can affect the mental representation held by the user. Thus, an interface that reflects the structure of a system will aid the user in navigating that structure. An interface that is poorly organised and does not make relationships clear can cause disorientation.

The most important characteristic to note about mental representation is that they describe an individual's

understanding of a particular content domain; in other words it is domain dependent. Craik (1947) is generally considered to be among the first theorists (Johnson-Laird, 2004) to discuss the concept of 'mental models'. He argued that the fundamental property of thought is the power to predict events. Sensory stimulation translates into neural patterns, which in turn are translated into excitation of the motor organs. The brain imitates or models the physical processes it is trying to predict, so for example, instead of building a bridge to see if it works, you envisage how to build it. The main difference between the Craikian and the modern theory of mental representation is iconicity. In Craik's view, a model imitates reality, but its structure can differ from the target domain (what it is meant to represent). In today's view, mental representations are usually considered to mirror the target domain (Johnson-Laird, 1983; 2004). Johnson-Laird used the example of how a model of the world can be three-dimensional for processes such as spatial reasoning, but that this does not necessarily call for a three-dimensional layout in the brain (or on a computer screen). For example, when presented with a two-dimensional hypertext representation or a floor plan of a house we can still translate and

make spatial inferences about the environment in three dimensions. The physical embodiment merely supports the representation. This is of particular importance in the context of the present research, as it is part of what makes interface metaphors work. Internal representation generally becomes more sophisticated with increased experience (Johnson-Laird, 2004). Experts consolidate their knowledge structures in a highly efficient way. It is thus considered helpful to map externally experts' knowledge structures for novices. For example, hypertext environments, can be used as a scaffolding tool to present visually experts' conceptual framework of a subject domain to learners.

The term 'mental model' is popular among computer scientists and interaction professionals. However, it is unclear what the concept actually means. It is often confused or used interchangeably with other related terms, such as mental imagery and cognitive mapping. According to Williams, Hollan and Stevens (1983), a mental model is a collection of connected 'mental object [s, each] with an explicit representation of state, an explicit representation of its topological connections to other objects, and a set of internal parameters' (p. 133). Staggers and

Norcio (1993) considered mental models as visually structured propositions that consist of objects and the relationships between objects. From a computer professional's point of view, Marcus (2002) described mental models as "organization of data, functions, tasks, roles, jobs, and people in groups at work or play" (p. 48) as they are learned and observed by users. According to Norman (1983), mental models evolve through interaction; their quality and 'shape' is largely dependent on the individual's characteristics. Johnson-Laird (1983) held that mental models cannot be defined:

"At present, no complete account can be given - one may as well ask for an inventory of the entire products of the human imagination - and indeed such an account would be premature, since mental models are supposed to be in people's heads, and their exact constitution is an empirical question." (p.6)

The term 'mental model' cannot be applied to the present research in any meaningful way. Therefore, the term 'mental representation' will be used to refer to users' understanding and knowledge of the structure, content, and interaction with hypertext environments. There are, however, a few more qualifications that need to be made. It is important to distinguish mental representation from mental images. Mental images preserve a lot of the information available in visual images, such

as size and distance (Rinck, 2005). It should be noted that researchers generally avoid the reference to mental imagery as 'images in the head'. Although a philosophical dilemma, equating mental images with perceptual images is a position that was disparaged some four decades ago by Shepard and Chipman (1970). Rather the format of the underlying representations is purely propositional and based on tacit knowledge (Pylyshyn, 2003). This perspective is relevant for the interpretation of visuospatial task data. During, for example, mental rotation tasks, we use our tacit knowledge of what it would be like to see something in actual visual perception which produces the linear reaction time patterns typically observed.

It is also necessary to draw a distinction between mental representation and cognitive maps. Although the terms cognitive maps and mental representation are sometimes used interchangeably, these are two distinctive streams of research. A term coined by Tolman (1948), cognitive mapping refers to the process of sensing, encoding, and storing experienced information to form declarative knowledge. Cognitive maps consist of mental representations that individuals draw on in order to solve problems involving spatial relations between

locations (Golledge & Gärling, 2004; Gärling & Golledge, 2000). Cognitive maps are often inaccurate, fragmented, and incomplete; and for this reason Tversky (2005) prefers the term 'cognitive collage'. In essence, cognitive maps can be seen as forming part of mental models.

Mental representations share their theoretical origins with schema theory (Mandler, 1984). Some psychologists see schemata as the building blocks of cognition (Downs & Stea, 1977; Johnson-Laird, 1983; Mandler, 1984; Rumelhart, 1980); in other words, all mental organisation is schematic in nature. Schemata are mental representations of the properties that concepts generally have, for example what a terraced house usually looks like (Rinck, 2005). In navigation terms, schemata provide users with a frame of reference, making orientation easier. Downs and Stea suggested that these frames of reference exist at all levels from the global to the specific. Schemas are quickly acquired, and once a generic model has been developed (e.g. of the contents and characteristics of a 'city'), people soon know what to expect when they visit one. It is quite possible that experienced hypertext users have a schema for hypertext structures, and that this might

affect their ability to navigate these structures (Otter & Johnson, 2000).

Schema theory proposes that when individuals obtain knowledge, they attempt to fit that knowledge into some structure in memory that helps them make sense of that knowledge. As individuals encounter new information, they add this information to their schemata, which are organised in networks of different, interrelated categories. Mandler's (1984) model of schematic processing of stories is particularly relevant to hypertext environments. According to Mandler, story schemata contain nested episodes, which in turn contain one or more nested constituents. This model implies that the mental representation for stories is organised in a hierarchical manner. Furthermore, story schemata are temporally ordered. This is necessary for keeping track of what has gone on before, and at what point the story is complete.

Van Dijk and Kintsch's (1983) model of strategic information processing contains components similar to both those of mental representation and schema theory. In essence, the model describes the reading process as consisting of three different mental representations of a text: verbatim

representation, semantic representation, and a representation of the situation to which the text refers. The situational representation is comparable with Johnson-Laird's (1983) mental models in that it refers to "the cognitive representation of the events, actions, persons, and in general the situation, a text is about" (p. 11). Van Dijk and Kintsch argued that readers use a schematic processing strategy when encountering a discourse type with which they are familiar. This strategy states that a reader "will try to activate a relevant superstructure from a semantic memory as soon as the context or the type of text suggests a first cue" (p. 16). Subsequently, the reader uses the superstructure to process the text in a top-down fashion. Hypertext systems, with their typical hierarchical layout, can be considered a discourse type in itself. Users have certain expectations about the structure of a webpage. For example, Oulasvirta, Kärkkäinen and Laarni (2005) examined users' expectations of the location of hyperlinks by recording eye movements. Findings indicated that when asked to locate a target hyperlink, users tended to focus on the left-hand side of the screen, the area that typically contains the menu of a website.

The three concepts presented in this section are related on more than one level. Despite differences in terminology, the basic assumption is that humans seek order and patterns in trying to make sense of incoming information.

2.1.3. Dude, where's my information? Disorientation in Hypertext Environments

Disorientation, or the tendency to lose one's sense of location within a hypertext environment, can cause users to become frustrated, lose interest, and experience a measurable decline in efficiency (Ahuja & Webster, 2001). Hypertext structures can be complex, richly interconnected and cross-referenced bodies of information, but they have since the early days of the Web had the potential to be what Utting and Yankelovich (1989) called "complex, disorganised tangles of haphazardly connected documents" (p. 58) that can make it very difficult to locate information

Researchers (e.g. Calisir, Eryazici, & Lehto, 2008; George Saade & Alexandre Otrakji, 2004; Hammond & Allinson, 1989; Herder, 2003; Kim & Hirtle, 1995; McDonald & Stevenson, 1996) have claimed that because of its structure, a hypertext document, even if containing the same amount of information as a traditional linear text, resembles a more complex text cognitively.

This complexity is one of the factors causing disorientation. The literature often divides hypertext disorientation into two categories, structural disorientation and conceptual disorientation. Structural disorientation refers to Conklin's definition of disorientation (Conklin, 1987), reflecting a cognitive load linked to the processing of physical space (e.g., location of the position in the physical space, representation of the previous path). Conceptual disorientation, on the other hand, concerns the users' difficulties to link meaningfully the different concepts contained within a hypertext (Cress & Knabel, 2003).

Disorientation manifests itself as confusion and frustration and leads to time being wasted moving around an information base, reducing the effectiveness of the system. Elm and Woods (1985) described disorientation as the user not having a clear conception of the relationships within a system, not knowing his/her present location in the system relative to the overall structure, and finding it difficult to decide where to look next within the system. This description focuses on an objective measure, decreased performance, rather than subjective feelings of being lost: the problem is linked to the mental model rather than the external guidance. Consequently, to reduce

disorientation, guidance needs to be provided to help users construct mental models, rather than simply alleviating the feeling of disorientation.

Empirical Investigations of Hypertext Disorientation

Disorientation has been operationalised and quantified in a number of different ways throughout the electronic navigation literature, making it difficult to draw consistent conclusions from research. A common way to measure *structural* disorientation is to calculate the minimum number of nodes a user needs to visit in order to solve a navigation task and compare this to the actual number of nodes the user visits (e.g. Ahmed & Blustein, 2006; Smith, 1996). Other researchers have focused on the navigation trajectory; Boechler (2001) and Herder (2003) used 'looping behaviour' (revisiting nodes) as an indicator of disorientation. *Conceptual* disorientation is often measured either by tests measuring understanding or recall of contents (Amadiou, Tricot, & Mariné, 2009) or by sketching conceptual maps (Padovani & Lansdale, 2003). A more subjective approach involves administering post-test questionnaires asking participants to rate their feelings of disorientation (Ahuja & Webster, 2001)

There are two typical approaches to overcome the problem of disorientation. The first consists of giving users more cues, such as maps or other spatial cues, in order for them to orientate themselves; (Ahmed & Blustein, 2006; Dias & Sousa, 1997; Folz, 1991; Hammond & Allinson, 1989). The second involves attempts to make the structure more linear by providing paths through the information relating to a specific goal. The objective is not just to aid information access, but also to facilitate the formation of mental models of the environment, thus enabling users to find their way around more easily (Bernstein et al., 1991; Edwards & Hardman, 1989). Levels of disorientation are frequently found to be affected by individual differences; and the two areas that have received the majority of attention in the disorientation literature are cognitive style and spatial ability (Ahuja & Webster, 2001; McDonald & Stevenson, 1996; Qin & Rau, 2009). The lack of consistency in terms of measures and methodology, and also the limited empirical evidence of the potential between disorientation, individual differences and environment characteristics, suggests that further investigation is needed in order to start gaining an overview of the area.

2.2. Metaphor as a Cognitive Tool

Up until the early 1980s, metaphor was considered a purely linguistic phenomenon by most scholars; a poetic flourish that was merely decorative language where one or more words for a concept are used outside of their normal conversation meaning to express a similar concept (known as a simile) (Lakoff, 1993). Among the current cognitive theories of metaphor there is currently a handful of dominating approaches. One of these is the categorisation theory (Glucksberg & Keysar, 1993; Glucksberg, 2003) which holds that metaphor as a form is more basic than simile because metaphors are inherently categorisation statements and similes are implicit categorisation statements. A second theory relies on the notion of comparison to explain metaphor; in other words that metaphor is equivalent to analogy in that it involves the mapping of structure and attributes from one domain to another (Gentner, Falkenhainer, & Skorstad, 1988). A third theory was proposed by Lakoff and Johnson (1980). This theory emphasises that metaphor is a conceptual rather than a linguistic process. Rather than a mere interaction between two words, metaphor is the interaction between a source (familiar area of knowledge) and a target domain (unfamiliar area of

knowledge or situation), involving the interaction of schemas and concepts; in other words, metaphors are systematic thought structures (Figure 1 illustrates this cross-domain mapping). With some support from Gentner and Bowdle (2001) they also hold that all abstract language, including metaphor, must be grounded in embodied physical experience, and that any abstract concept can be shown to depend on mental images. Embodied metaphors are typically understood as operating at a preconscious or sensori-motor level (Antle, Courness, & Droumeva, 2009); they arise unconsciously from experiences relating to the body's movements, orientation in space, and its interaction with objects (Johnson & Hasher, 1987). Lakoff and Johnson used the example of how the body's general upright position in space creates a verticality schema, which has given rise to various spatial metaphors based on a vertical hierarchy (e.g. hypertext menu system).

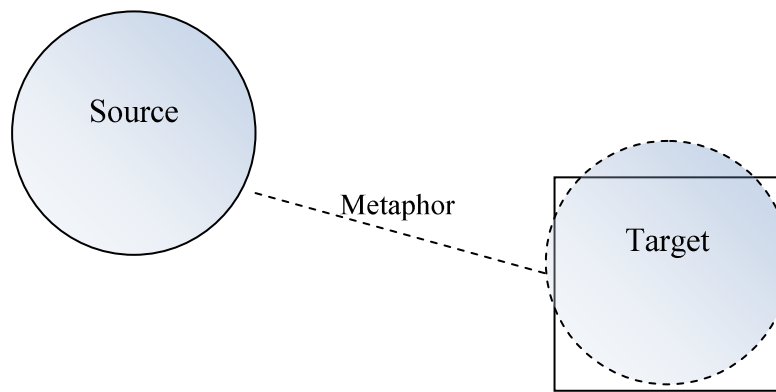


Figure 1. A model of cross-domain mapping (after Wulff, Evenson, & Rheinfrank, 1990).

Belonging to Lakoff and Johnson's (1980) school of thought, Balconi and Tutino (2007) stressed that metaphor is not only to be understood in terms of 'figure of speech', but also as involving specific cognitive operations such as conceptualisation, semantic memory activation, internal representation, and semantic attribution.

2.2.1. Making Sense of Digital Information: Metaphors in Interaction Design

The use of metaphors in user interfaces enables users to 'translate' and reuse knowledge about everyday real-world for objects in the virtual world. The provision of metaphor can thus be justified on educational grounds, the main areas being learning and problem solving. A major barrier associated with user interfaces is often described as a 'learning curve', and this barrier can be removed or reduced by allowing users to build on

experience from other areas (Blackwell, 2006). Ideally, metaphors are used to develop new concepts by means of triangulation (Petrie & Oshlag, 1993): individuals recognise anomalies in their existing knowledge and create new knowledge by correcting their mental model to accommodate both sources. Thus, an important advantage of metaphor in interaction design is that it can aid problem solving: when users experience problems with computer based material, they can solve these by analogy to solutions that might apply to the metaphor domain. There is substantial literature describing this analogical approach to problem solving when interacting with computers (e.g. Boring, 2002; Finstad, 2008; Holyoak & Thagard, 1999). Because metaphors exploit specific knowledge users have about objects or situations in daily life in the electronic environment, they enable users to make use of existing knowledge and apply this to the interface. For example, a command 'menu' can be understood by analogy to choosing one of the dishes listed on a restaurant menu (Blackwell, 2006).

A certain conflict or tension between the extended functionality of a computer system and the metaphorical grounding achievable when it comes to real-world source

domains is, however, unavoidable. Critics (e.g. Black, 1993) of the metaphorical user interface have claimed that metaphors can encourage 'sloppy thought' in that they may be over-extended and inappropriately reduce complex matters. Furthermore, researchers have expressed concerns regarding the source-target mapping, in that a metaphor can never cover the whole domain of its referent (e.g. Nardi & Zamer, 1993). Metaphors do not represent the real world perfectly; instead they omit various features and provide other new ones. This problem is often referred to as the tension between literalism and magic. Literal features are functionally consistent with their real-world counterparts; magical features extend beyond what is possible in the real-world (Dieberger, 1994a; 1994b). Although inaccurate mapping between target and source domains can lead to problems with forming accurate mental representations, it is also this lack of isomorphism that allows users to perform tasks that are not possible in other media, such as the quick skipping and backtracking between different segments (Neale & Carroll, 1997). Kuhn and Blumenthal (1996) suggested this kind of 'magic' features should be seen as complementing rather than contradicting metaphors; they allow users understand something

in terms of something else, but do not require the users to believe the two things are the same.

Do Interface Metaphors Contain Spatial Properties?

During the 1990s, a trend emerged where developers were striving to make graphical user interfaces more 'realistic', in that objects represented in an interface were made to look and behave as close to real-world objects as possible. An early example of this is the computer desktop where objects are moved like sheets of paper on a flat plane. Metaphors do not offer precise descriptions for use; rather they offer some level of concreteness and suggest how users may interact with a system. The general purpose behind interface metaphors in general is to aid problem solving, making it easier for users to 'make sense' of a computer system. In short, metaphors enable users to understand target domains in terms of familiar source domains. Chignell and Waterworth (1997) argued that "the overall metaphor of multimedia and hypertext is generally assumed to be spatial. In this spatially oriented view of multimedia, browsing is a process of navigating through some information structure" (p. 1817). By 'spatial', they implied that it has qualities such as height and depth. Stanton, Correia and Dias (2000) suggested that in general "most of the hypermedia environments are conceived as spatial ones, based on

the spatial metaphor, that may be explored by the same rules used in the physical ones.” (p. 265). The usefulness of spatial metaphors is therefore connected to the analogy between navigation in real-world environments and information environments. Canter et al. (1985) emphasised the psychological processes involved in navigation, arguing for the usefulness of a direct parallel “between navigating concrete environments, such as cities or buildings, and navigating data. After all, such parallels are implicit in the navigation metaphor, so it is worth establishing whether or not there is a fruitful analogy between the psychological processes involved” (p. 93). What follows from this is that if indeed users conceptualise hypertext in spatial terms, then the spatial abilities people draw on to navigate in the real world will also be useful when exploring hypertext systems (e.g. Calvi, 1997; Kim & Hirtle, 1995).

Jonassen (1989; Jonassen & Grabinger, 1990) drew parallels between memory and hypertext, arguing that “schema are to memory as nodes are to hypertext. They are the building blocks of memory and hypertext. Hypertext resembles memory” (p. 23). If people perceive hypertext systems in terms of spatial properties, the schemata they form would contain spatial information.

Empirical Investigations of Metaphors in Interaction Design

Considering that interface metaphors are assumed to have substantial theoretical benefits, there is still surprisingly little evidence to support this. Boechler (2001) stated that there has been little examination of the use and nature of conceptual metaphors in the minds of computer users. Whilst a recent literature search provides support for this comment, a qualification based on research focus needs to be made here. There are many studies reporting performance and/or preference for one metaphor or another (e.g. book versus folder metaphor: for a review, see Spiro, Feltovich, Coulson & Anderson, 1989), or metaphor versus no metaphor. However, most of these examine simple symbols and analogies relating directly to the format of the material presented, in particular those based on the 'office' construct (e.g. with 'desktops', 'filing cabinets', and 'folders').

Although numerous websites exist reproducing familiar locations and objects (e.g. websites for children), there appears to be a lack of empirical research in the area that examines metaphors based on more general or expansive 'themes' (but with structures familiar to the user). A handful of studies have explored this type of metaphors: Padovani and Lansdale (2003)

examined spatial (house layout) and non-spatial (social relationships); Hsu (2006) compared no metaphor with a post office mailing system metaphor; and Lee (2007) examined a standard hyperlink interface (hierarchical-associative structure) versus a visual metaphorical interface (similar overall structure but based on a student dormitory building). A metaphor of this type based on, for example, a building, represents content and object connectivity in spatial form. Thus, rather than being associated necessarily with the specific nature of the information or its presentation, these types of metaphors are developed from embodied experience and repeated encounters with the target domain, providing a generic and frequently implicit framework for interaction. These types of metaphors are based on perceptual patterns that emerge during sensorimotor activity as we manipulate objects, seeking spatial and temporal orientation (Gibbs, Costa Lima, & Francozo, 2004).

With the exception of Padovani and Lansdale (2003), little is known about the cognitive aspects of interface metaphors, and how these affect behaviour and performance. Farris, Jones and Elgin (2002) belong to the minority of researchers who have challenged the idea of hypertext as a spatial environment. They argued that hypertext is inherently non-spatial; qualities such as

depth and direction in hypertext are merely abstractions and as such qualitatively different from depth and direction in a physical environment. Exploring hypertext systems does not involve movement in the physical sense, and therefore does not provide the user with spatial information. According to Farris et al., "it is illogical to assume that users incorporate spatial information into their schemata of a hypermedia system, when no such information is present" (p. 490). They tested their assumption by having a sample of 40 university students explore four websites containing the same information, but with links arranged in hierarchies of one, two, three and four levels. The participants were asked to draw maps of the websites, and results showed that rather than reflecting the hierarchical layouts of the websites, the drawings reflected the conceptual relationships within the information. It is important to note that Farris et al. were questioning the idea of an inherent spatiality of hypertext systems, and not whether hypertext is embedded in a metaphor based on a different source domain. The present work focuses not so much on the spatial qualities of hypertext in itself, but rather on whether users attribute spatiality to hypertext by means of a spatial metaphor. As in the study by Farris and colleagues, if this is indeed the case, then some form of spatial

organisation will be integrated in the users' mental representations of the system.

In sum, the type of metaphor used to conceptualise the overall structure of a hypertext environment has been found to influence navigation performance; however, less is known about the inherent spatial and semantic properties of the metaphors and their effect on performance and formation of mental representations. Furthermore, little is known about how metaphor relates to the layout or structure of the information presented on screen. Dependent on the relative strength of the effects of layout/ structure and interface metaphor, there is a possibility that interaction effects are present, and that one factor 'overrides' the effect of the other. The question then becomes whether one factor is of more importance for performance and accuracy relative to the other.

2.3. Individual Differences in Interaction Research

The rationale behind studying individual differences in the context of computer interfaces is ultimately to be able to inform design decisions about computer interfaces and navigational tools in order to cater to the needs and preferences of users with

differing characteristics. Research on individual differences in behaviour and performance in computer use focuses on a number of different 'dimensions' of the users; e.g. physical, psychological and social factors; and therefore draws on a wide range of topics. Furthermore, some characteristics of an individual user are not fixed over time and are dependent on situation and context; which adds further variability to the interaction process. The present research therefore aims to account for individual differences when measuring navigation performance and behaviour, while also taking into consideration task context.

Previous research has shown that prior knowledge (Calisir & Gurel, 2003; Calisir et al., 2008; Chen, Fan, & Macredie, 2006), cognitive styles (Calcaterra, Antonietti, & Underwood, 2005; Chen & Macredie, 2001) and visuospatial ability (Ahmed & Blustein, 2006; Stanney & Salvendy, 1995) influence behaviour and performance in hypertext-based interaction. Moreover, these individual differences have certain inter-relations. For example, parallels have been drawn between cognitive processing style and prior knowledge in terms of interaction patterns. Studies have reported that individuals who prefer to process parts before wholes show similar behaviour patterns to domain experts (Ford

& Chen, 2000). The next three sections give brief introductions to the main factors previously mentioned: cognitive style, prior knowledge, and visuospatial ability.

2.3.1. Performance Manner: Individual Cognitive Processing Style

Two users may be able to retrieve the same information from hypertext environment equally efficiently, but how they go about the task may be different. Individual users have their own idiosyncratic approaches to hypertext navigation, and in this context the concept of cognitive style is particularly interesting.

It is important to note that cognitive style is a different concept from 'learning style', although the two terms are often used interchangeably. Learning style is used widely in education and training, and refers to constructs ranging from instructional preferences to cognitive style. It deals with characteristic styles of learning and information processing taking place specifically in a learning context, for example active versus passive (Kolb, 1984) and can be changed over time (Ford & Chen, 2001). Learning style, according to Curry (1983) is more open to introspection, more context-dependent and less fixed than cognitive style. Sadler-Smith (2001) investigated the relationship between two frequently used measures of cognitive style and learning style;

specifically the Cognitive Styles Analysis (CSA: Riding, 1991, 1998; Riding & Rayner, 1998) and the learning styles Inventory (LSI: Kolb, 1984); and found no significant relationships between the two.

Cognitive style is more fundamental as a construct than learning style, and relates to an individual's innate processing style. There are many different definitions of cognitive style. Atkinson (2004) defined cognitive style as "a distinct and consistent way for an individual to encode, store, and perform" (p. 663). Riding, Glass, and Douglas (1993) termed cognitive styles as "a fairly fixed characteristic of an individual" (p. 268) and as static and "relatively in-built features of the individual" (p. 268). At the time referred to as 'perceptual attitudes', the concept of cognitive style was first introduced by Klein and Schlesinger (1951) and Klein (1951), who were interested in possible relations between individual differences in perception and personality. Unlike individual differences in abilities (e.g. Gardner, 1993; Sternberg, 1999), which describe peak performance, cognitive style describes an individual's typical mode of thinking, remembering or problem solving (Riding & Rayner, 1998; Riding, 2000). Having more of a particular ability is

usually considered beneficial while having a particular cognitive style simply denotes a tendency to behave in a certain manner. Both style and ability may influence performance on a task, but where performance improves as ability improves, the effect of style on performance is dependent on the nature of the given task. In addition to Klein, Witkin and colleagues (e.g. Witkin et al., 1954) were among the first to put forward this idea of bipolarity (i.e., value-equal poles of style dimensions). The main experimental paradigm, particularly in early style research, usually involved presenting a simple task with two or more possible solutions. In situations of uncertainty about the 'right way' of performing the task, the individual would choose his or her preferred way. A participant group would then be divided on the basis of their performance via a median split, forming two opposing poles of a particular style.

Although the main tenet of styles research was that bipolar dimensions represented two equally efficient problem solving strategies, it was frequently the case that one strategy would actually be more effective than the other. One of the instruments for which this was particularly evident was the Embedded Figures Test (EFT: Witkin, Oltman, Raskin, & Karp, 1971). This

test was one of the more commonly used instruments, and measures cognitive style in terms of field dependence-independence. Field independence refers to an individual's tendency to discern and to isolate elements embedded in complex contexts, whereas field dependence is the tendency to view the whole rather than discrete parts (Calcaterra et al., 2005; Witkin, Moore, Goodenough, & Cox, 1977; Witkin & Goodenough, 1981). Riding and Cheema (1991) noted a fundamental problem with the EFT in that low scoring individuals are assumed to be field dependent, although low scores can be due to any number of factors (e.g., motivation, quality of instructions, or visual impairments). The EFT tasks involve identifying a small geometric figure embedded within a larger one, and style labels are given based on speed (fast time on task = field independent). Since the EFT measures speed of processing, it is therefore not surprising that researchers who have investigated the correlation between intelligence tests and conventional measures of field independence such as the Rod-and-Frame or EFT (e.g. Cooperman, 1980; Farr & Moon, 1988; MacLeod, Jackson, & Palmer, 1986; McKenna, 1984) consistently report higher intelligence among individuals with a field independent style

than among those with a field dependent style. Martinsen and Kaufmann (1999) claimed the problem with bipolarity was not just limited to the EFT, arguing that for most style constructs one pole tends to be valued more than the other.

Because cognitive styles are measured on a continuum between two extremes (e.g. field independent to field dependent) a problem with consistency occurs when researchers use the median split criterion in order to create style categories. To illustrate, in a review of one of the cognitive style dimensions (impulsivity–reflectivity), it was found that norms were only used when assigning style labels in 8% of all the studies, making it difficult to compare findings across studies (Walker, 1986). Another problem related to the lack of theoretical coherence, Kozhevnikov (2007) noted the majority of studies of cognitive styles tend to be descriptive, rather than examining the underlying nature of the construct or relate styles to information processing theories. Consequently, much of this work suffers from arbitrary distinctions and overlapping dimensions.

Since the 1990s the on-going trend among researchers has been to attempt to unite and systematise multiple style dimensions into more coherent models (Rayner, 2011). Among

the measures emerging from this is the CSA (Riding, 1991, 1998; Riding & Cheema, 1991; Riding, Glass, & Butler, 1997). This measure amassed a strong body of empirical evidence in support of its construct validity. The test is based on a superordinate model of cognitive style consisting of two orthogonal dimensions, verbaliser–imager (VI) and wholist–analytic (WA). In contrast to the EFT which only measures one pole of the style dimension (field independence), the CSA was designed to assess positively each pole of the two dimensions (see Figure 2). The Visual-Imagery (VI) dimension refers to the mode in which individuals prefer to represent information in memory, verbally or in the form of images. The Wholist-Analytic (WA) dimension is conceptualised as an individual's preference for processing information either in complete wholes or in discrete parts. Furthermore, wholist style is associated with processing information on a wider, more superficial level, whereas analytic style is associated with processing less information but at a deeper level. What is important to note is that irrespective of definitions, cognitive style is more concerned with patterns of abilities and differences in manner of performance than with quantifying ability levels.

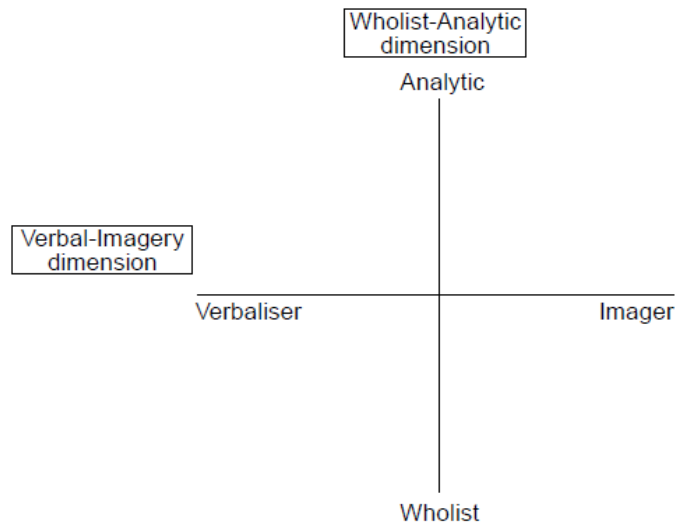


Figure 2. The Two Dimensions of Cognitive Style, figure based on Riding and Sadler-Smith (1997).

Riding and Cheema did not provide a theoretical basis for their model, and studies (Peterson, Deary, & Austin, 2003a; 2003b; Rezaei & Katz, 2004) have reported poor test-retest reliability of the CSA and low internal consistency for the VI dimension. Although Riding (1997) reported a number of studies to support the validity of the CSA test, these reports are mostly based on the construct validity (i.e., low correlation between two orthogonal scales) and the discriminant validity of the test (i.e., the lack of correlations among test scores and intelligence, gender, and personality).

2.3.2. Linking Cognitive Style to Prior Knowledge, Experience and Confidence

Cognitive style and prior knowledge have certain inter-relations. Different ways of approaching, learning and organising material may affect how a person uses a computer system, which in turn affects the prior knowledge and outcome of the interaction. For example, wholists and individuals with little prior experience or knowledge show similar preferences in their navigation patterns, in that they prefer taking non-linear paths (Ford & Chen, 2000). In the context of the present research, the term experience is understood as the individual's interaction with computer technology, and not in terms of quantifying exposure (for which the term computer use is adopted). The concept of computer experience has been defined and conceptualised and measured in a number of ways in the literature. Not only is there little agreement about how to measure computer use, there is an additional problem in that the terms 'use' and 'experience' are applied interchangeably. Potosky and Bobko (1998) defined computer experience as a combination of motor skills, technology-related knowledge and aptitude, and motivational aspects. Smith, Caputi, Crittenden, Jayasuriya and Rawstorne (1999) stated that it is necessary to differentiate

between objective and subjective measures of computer experience; the former referring to quantifiable computer use (i.e. time and frequency of exposure), and the latter to the subjective experience of using computers. The majority of research tends to focus on objective experience; a frequent method of quantifying experience is by years and hours of use (Garland & Noyes, 2004).

It is important to mention computer attitudes in this context. There are numerous studies demonstrating positive relationships between computer attitudes and length of exposure to computers (Bozionelos, 2001; Levine & Donitsa-Schmidt, 1998; Loyd, Loyd, & Gressard, 1987; Pope-Davis & Twing, 1991; Potosky & Bobko, 2001; Shashaani & Khalili, 2001) and studies have shown that owning a computer is generally related to more positive attitudes (Rhoads & Hubele, 2000; Teo, 2008). How people feel about computers and technology can greatly affect their interaction (e.g. Alexander, Kulikowich, & Jetton, 1994; Liaw, Chang, Hung, & Huang, 2006), and on a general level, negative attitudes have been found to act as a barrier for some users, hampering learning from computer-based material (e.g. Massoud, 1991). Popovich, Hyde, Zakrajsek, and Blumer (1987) found computer attitudes to be positively correlated to number of

hours per week spent using computers and to amount of computer courses taken, however in a follow-up study two decades on, Popovich, Gullekson, Morris, and Morse (2008) found only hours of use were still significantly related to computer attitudes. Popovich and colleagues attributed their findings to the change in computer use that has taken place over time, in particular to the increased use of electronic material in education settings. Garland and Noyes (2004) had similar findings, but in addition to hours of use per week, also differentiated between hours at home or at university (as they used a student sample). Results showed that there was a relationship between computer attitude and voluntary use (hours spent using the computer at home), but not between attitudes and 'required' use (hours spent using computers at university). This suggests that frequency of use is related to choice and preference for use, which in turn is reflected in more positive attitudes.

Garland and Noyes (2004) commented on the complexity of the relationship between prior knowledge, computer experience and computer attitude. As with the attitude construct, there are major discrepancies within the literature on of how to

define and operationalise experience. Some scales measure exposure, for example length and frequency of use (e.g. Ertmer, Evenbeck, Cennamo, & Lehman, 1994), whereas other scales measure breadth of use in terms of the type of activities in which people engage, such as gaming, word processing and web surfing (Schumacher & Morahan-Martin, 2001). Other scales again appear to measure computer attitudes, although they are intended to measure experience. Panero, Lane and Napier's (1997) Computer Use Scale measures users across the dimensions enthusiasm, entertainment, efficiency and communication, something that Garland and Noyes (2008) remarked focuses more on the emotional aspects of computer use, which is one of the components of attitude, rather than exposure or use.

In sum, measuring computer attitudes and extent of use has traditionally been viewed as important part of the evaluation of behaviour and performance. However, due to the proliferation of computer technology, recent evidence (Garland & Noyes, 2008) suggests there is no longer a strong relationship between computer use and attitude, and that existing attitude measures may not be sensitive enough to register what have now become very subtle differences among users. It therefore seems that

measuring computer attitude will not be of limited relevance for the type of performance measured in the presented research.

2.3.3. Visuospatial Perception and Hypertext: Main Issues

Visuospatial ability can be defined as the ability to generate, retain, retrieve, and transform visual images, and to conceptualise the spatial relationship between objects (Halpern, 2000). The visual system enables humans to perceive objects and the space they are contained in as three-dimensional. However, objects do not necessarily need to be presented three-dimensionally in order for people to perceive an object spatially. Spatial objects can be represented on a flat surface as a drawing by means of perspective, in other words transforming spatial objects into a representation on a flat space. The viewers' interaction with and knowledge of the real world enables them to perceive a flat picture as a spatial construct (e.g. Klatzky, Loomis, Beall, Chance, & Golledge, 1998). This concept is of particular relevance in relation to hypertext and other electronic environments presented on a flat computer screen. People are generally very good at processing the visual field, and at 'translating' observed sequences of two-dimensional images to views of objects in a three-dimensional space (e.g. Shepard & Metzler, 1971); in fact, it has been claimed that 'the visual system

attempts to interpret all stimulation reaching the eyes as if it were reflected from a scene in three dimensions' (Haber & Wilkinson, 1982, p. 25). A flat representation contains less spatial information than the real object; the missing information is 'filled in' by the brain's image processing.

In order to account for spatial ability in hypertext navigation there are two issues of immediate relevance: how is a hypertext system presented on a screen conceived of spatially – is it large- or small-scale, or both and what type or aspect of spatial ability should be the focus? From a neuroscientific perspective, there is evidence suggesting different brain structures are involved in processing different scales of spatial information. Small-scale spatial processing (e.g. mental rotation) is mainly associated with the parietal lobes (Kosslyn & Thompson, 2003). Processing of large-scale spaces activates the hippocampus and surrounding areas in the medial temporal lobes (Morris & Parslow, 2004). Early evidence of this was O'Keefe and Nadel's (1978) detection of so-called place cells located within the hippocampus. There has not been a discussion within psychology or interaction design concerning the cognitive scale of hypertext environments specifically; however a useful conceptualisation is that of patterns of visibility (Benedikt, 1979; Kadar et al., 1995;

Kadar & Shaw, 2000; Woods et al., 1990), and the integration of vantage points into a larger whole. Following this it can be argued that hypertext is both large- and small-scale. The overall system has the characteristics of a large scale space that extends beyond the user's immediate view, and the information available on-screen at any given moment can be characterised as small-scale. If this is a useful way of conceiving of hypertext space, then both small- and large scale spatial abilities would be relevant to performance and behaviour.

There is an on-going debate concerning whether spatial ability is a unitary concept or not. This issue focuses largely on the issue of scale and whether the processing of large- and small-scale environments taps into the same cognitive resources or not. According to the unitary model, spatial abilities at the two scales of space are completely overlapping, in other words depending on exactly the same cognitive processes. The Total Dissociation model proposes that the two sets of abilities depend on completely distinct cognitive processes (Hegarty & Waller, 2004; Montello, 1993). Hegarty, Montello Richardson, Ishikawa and Lovelace (2006) suggested that spatial abilities at different scales of space are partially associated. Three important abilities are

shared: the ability to encode spatial information from visual stimuli, the ability to hold and manipulate representations in working memory, and the ability to draw inferences from spatial representations. A comparable theory was proposed by Downs and Stea (1977), who distinguished between perceptual space, which they defined as small-scale space studied by psychologists; and 'transperceptual' space, defined as large-scale space as studied by geographers.

The space of navigation serves to guide us as we move around in our surroundings, and can be seen as consisting of places that are interrelated in terms of paths or directions within a certain frame of reference (Tversky, 2005). Frame of reference is an important concept in this context, as this is what enables us to describe relations between objects in space. Frames of reference can primarily be based on viewer, object, or environment (Taylor & Tversky, 1996). According to Downs and Stea (1977) the concept can be applied to our surroundings on all levels of scale; north and south, upstairs and downstairs, urban and rural and so on. Schank and Abelson (1977) equated frames of reference to schemata in that they serve to guide our responses to the surroundings in terms of behaviour. Elm and Woods (1985)

described the demonstration of good spatial navigation skill as the ability to generate specific routes relative to task demands, to traverse or generate both familiar and new routes, and to develop of a concept of 'here' in relation to 'other places.

Should Electronic Environments be Considered Large or Small-Scale?

Within the interaction literature, the focus has largely been on small-scale spatial ability. This is often measured through tasks such as mental rotation of shapes, solving mazes, paper folding, and finding hidden figures. These psychometric tests are similar in that they all involve perceptually examining, imagining, or mentally transforming representations of small shapes or objects that can be manipulated, such as geometric figures, blocks or sheets of paper (Cooper & Shepard, 1973; Hegarty et al., 2006; Qualls, Bliwise, & Stringer, 2000; Shepard & Metzler, 1971). In a review of the literature on individual differences in spatial abilities, Hegarty and Waller (2005) concluded that small-scale spatial ability tests are not highly predictive of spatial ability in large-scale real world spaces; however they are closely related to the ability of processing the spatial characteristics of electronic environments. Hegarty and Waller claimed people perceive electronic environments, particularly desktop displays as small-scale stimuli with which they

interact, rather than navigate in the traditional sense of the term. They, like Dahlbäck (2003), suggested this is because desktop environments do not involve the users' whole body in the same way that moving around the real world does. As previously mentioned, navigating electronic environments on a desktop draws on a smaller array of perceptual cues than navigating physical environments, and may require users to rely more on processes associated with small-scale visuospatial abilities. However, following the theory of isovists (Benedikt, 1979; Kadar et al., 1995; Kadar & Shaw, 2000) electronic environments can also be viewed as large-scale. As with large-scale environments in the physical world, the viewer creates an overall representation of the environment by integrating smaller portions into a larger whole. It can therefore be argued that electronic environments contain elements of both large- and small-scale physical environments.

A recent literature search (as of August 2011) did not return any peer-reviewed research examining 2D electronic environments such as hypertext systems from a large-scale perspective or in relation to large-scale spatial skills. However, spatial visualisation, a type of small-scale spatial ability, is often cited as a good predictor of individual's performance in human-computer interactions (Egan, 1988; Stanney and Salvendy, 1995).

Examining performance on a search task within a hypertext-like hierarchical file system, Vicente and Williges (1988) found that users with high visuospatial ability completed their tasks faster than users with lower visuospatial ability. Similarly, Campagnoni and Ehrlich (1989) found evidence for the importance of visuospatial ability in that users with high visuospatial ability were quicker at retrieving information in a hypertext system.

Using the Paper Folding test (Ekstrom, French, Harman, & Derman, 1976) and Baddeley's three-minute intelligence test (Baddeley, 1968), Nilsson and Mayer (2002) found that individuals scoring high on these two tests, in particular the Paper Folding test had to visit fewer nodes to complete a search task within a hierarchical website. Czerwinski and Larson (2002) examined navigation performance in a 2.5D² visual user interface. They found that time on task was negatively related to visuospatial ability, and that users with lower visuospatial ability explored fewer of the available hyperlinks and topics. Users with lower visuospatial ability were also more likely to get lost, and to complete fewer search tasks. Ahmed and Blustein (2006) obtained

² 2.5D refers to 3D electronic environments (for example computer games) that use polygonal graphics to render the environment and/or characters, but where the actual interaction is restricted to a 2D plane. This is for example seen in games where the action is limited to 2D, but the environment has a 3D 'backdrop'.

similar results in a study designed to assess the usefulness of 'breadcrumbs' (trails showing which pages a user has visited). Participants with high visuospatial ability visited a lower number of nodes to complete a website search task than those with low visuospatial ability, in other words were closer to the minimal (or 'optimal') search path.

In sum, with reference to navigation there are a few issues regarding spatiality that makes it difficult to determine accurately the role of spatial abilities. As discussed earlier, there is the issue of similarities between real-world navigation and navigation in smaller, two-dimensional spaces. As an extension of this, although research favours the small-scale perspective, it is not entirely clear whether hypertext environments should mainly be viewed as small- or large-scale environments. Furthermore, there is some disagreement concerning whether hypertext interfaces can be considered 'spatial' or not.

2.4. Research Focus

Among researchers and developers, there are generally two main approaches to identifying problems in hypertext navigation and disorientation. Some hold it is a problem within the mind of the end user, relating it to users developing incorrect

or incomplete conceptual models (e.g. Elm & Woods, 1985) and cognitive factors such as distractibility, memory and experience (e.g. Ahmed & Blustein, 2006; Amadiou, Tricot, & Mariné, 2009); others argue it is mainly down to the geometric or structural properties of the hypertext (e.g. Lin, 2003; Saade & Otrakji, 2004). A more constructive way to conceive of being 'lost in hyperspace' is that it is a problem in communicating the structure of an information domain clearly to the user (e.g. Bernstein et al., 1991); the term structure referring to both spatial and conceptual properties of the system. Thus, navigation in hypertext is not simply a problem inherent to the hypertext or the user; it is a problem belonging to the interface between the user and the computer.

A difficult issue within the literature concerning hypertext navigation performance is inconsistencies in the methodological approach, not only between the different research fields, but also within each area. In particular, studies drawing on cognitive psychology and individual differences research have produced discrepant results. This has made it difficult to establish how, or whether, the individuals' cognitive skills and preferences affect navigation performance. These discrepancies can be due to a

number of different factors, such as differences in tests chosen; how the variables are treated (e.g. discrete or continuous); and the type of experimental design and statistical techniques used. Furthermore; as is often the case with adopting an experimental approach within any area of social science, there is the issue of generalisability. Difficulties arise when attempting to apply experimental findings to everyday computer tasks and design of computer interfaces. These problems have led to certain 'disenchantment' with the cognitive approach; however an appropriate alternative is yet to emerge. Some researchers have argued for a drastic paradigm shift, adopting qualitative, ethnographic methodologies (e.g. Blomberg, Burrell, & Guest, 2008). Others are less radical, attempting to expand on the cognitive approach by drawing on other areas, such as geography (Dahlbäck, 2003).

Metaphors can be seen as a way of helping to contextualise a navigation task by providing a concrete framework for the task to take place in. The role of metaphors in current interface design as a cognitive tool is based predominantly on case studies, assumptions and common sense rather than empirical research. This in itself is not a unique problem, as the world of technology

has a substantially faster pace than that of academic research. Nevertheless, there is little work concerning the actual effects of metaphors on user behaviour and performance. Furthermore, as mentioned in Section 2.2.1, more work is needed in order to understand which aspects of metaphor, in other words characteristics of both the target and source domains such as geometry/spatiality and familiarity, affect user performance and behaviour and the extent to which this applies within different task context.

2.4.1. Specific Research Aims

The thesis concentrates on the hypertext navigation ‘experience’. Experience should here be understood as a collective noun rather than a quantifier; a means of conceptualising what constitutes the act of navigating a hypertext environment. The outcome of this experience is expressed not only through the user’s movements within the environment but also through the individual’s mental model of the environment; and the primary dependent variable is an externalisation of this, in the form of a visual ‘map’ created by the users. Thus, a key focus of this research is mental representation. The starting point of the research reported in this thesis is the popular assumption

that navigation in hypertext environments is similar to, as navigation in the real, physical world and therefore draws on the same principles.

Among the key properties the conceptualisation of hypertext systems in terms of real-world environments is based on are familiarity and spatial properties. These two properties are also important aspects underlying the rationale behind the use of interface metaphors. Making use of existing mental representations, often ones derived from the physical world, when working with computer material is the main driver of metaphors in interaction design. These metaphors can either apply to specific objects (e.g. a 'recycling bin'), or overall system conceptualisations (e.g. 'desktop') and are based on semantic and/or visual associations between computer and real-world environments. The rationale behind interface metaphors is to ease knowledge transfer and to promote an understanding of the semantics of interaction; in other words helping users make sense of a computer environment by enabling them to draw on pre-existing knowledge.

The purpose of the current work is to examine to what extent characteristics of the hypertext environment in itself (in

terms of document structure and interface metaphor), the task being carried out (search and retrieval) and the metaphor (familiarity, spatial properties) affect how users find their way around a hypertext system. In addition, the quality of the consequent mental representations they form of the environment is examined. Another area of investigation is how factors relating to the individual users affect their navigation experience and mental representations. The focus here is on prior knowledge, preferred cognitive processing style, and visuospatial ability: all of these factors have been identified in research as having significant but variable influence on computer use. The task within this research is to determine the extent to which they need to be accounted for within the context of hypertext navigation and mental representation, and if so, how best to measure them.

2.4.2. Modelling Interaction

In order to clarify the proposition of the present research, the process of interaction including the variables to be examined is illustrated in Figure 3.

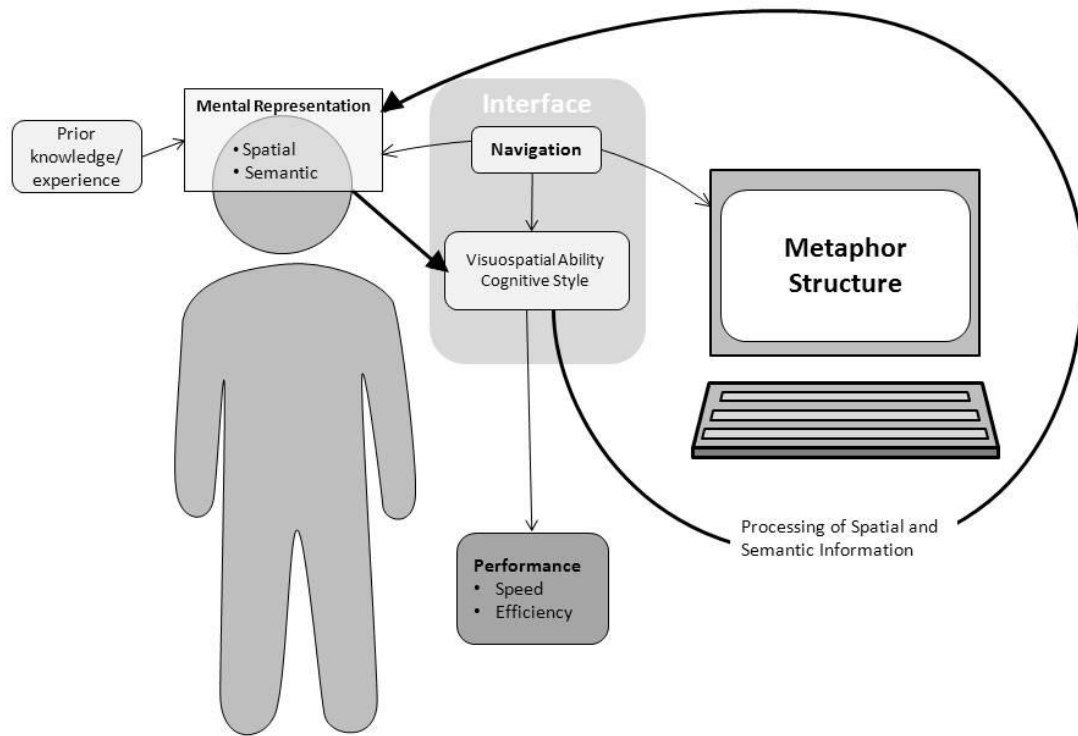


Figure 3. A conceptual model of hypertext navigation.

The figure is a conceptual representation only, not a cognitive processing model. The user approaches the interaction with a set of pre-existing attributes, in terms of knowledge and experience. Also entering into the interaction situation is the user's mental representation of the system consisting of spatial and semantic features. The user's approach to the navigation task is influenced by their cognitive processing style and visuospatial ability, which in turn affects the speed and efficiency with which they solve the task, and the way they process the spatial and semantic information presented to them via the hypertext system.

The hypertext system enters into the interface with a specific metaphor and structure which influence the way the underlying information is perceived and processed by the user. This in turn leads to changes taking place in the user's mental representation of the system. The process described here is essentially a feedback loop between user and system, where the interaction continually shapes how the user perceives the system and integrates this into their mental representation.

The primary research questions are:

- 1a. Does the metaphor in which a hypertext system is embedded affect navigation?
- 1b. In light of theories of mental representation and cognitive processing, what characteristics of metaphor affect performance and behaviour?
2. Do user individual differences (cognitive style and visuospatial ability) need to be accounted for when measuring navigation performance and accuracy of mental representation, and if so, in what situations?
3. Do the spatial structure and layout of the hyperlinks that connects the different parts of a hypertext system have an effect on behaviour, performance and accuracy?

4. Does the task carried out affect the influence of user and environment variables?

Chapter 3

3 Studies 1 - 2

3.1. Cognitive Style and Hypertext Navigation

This chapter outlines the general area of individual differences in interaction research and some of the approaches and existing evidence concerning hypertext navigation. The chapter describes two studies; the first was designed to assess measures of cognitive style, and the second was an initial exploration of hypertext navigation. The aim of the studies was to evaluate appropriateness and applicability of the measures in order to determine which should be included in further studies.

Individuals find their destinations in different ways. They use different representations of the environment, choose different reference points, and structure their knowledge differently. As in most areas of cognitive research prior knowledge and exposure affects the individual's performance; increased experience with computers in general and with hypertext systems in particular has been shown to improve performance, for example in terms of navigation efficiency (Calisir et al., 2008; Chen et al., 2006;

McDonald & Stevenson, 1998). Furthermore, experience is linked to the use of different cognitive strategies, which in turn affects navigation. Cognitive styles are related to the way in which individuals learn conceptual material and how they structure and process information (Riding & Rayner, 1998). Experience and cognitive style have certain inter-relations. Different ways of approaching, learning and organising material may affect how a person uses a computer system, which in turn affects the experience and outcome of the interaction. For example, wholists and individuals with little prior experience or knowledge show similar preferences in their navigation patterns, in that they prefer taking non-linear paths (Ford & Chen, 2000).

The most convincing evidence for the importance of cognitive style comes from research in applied, rather than theoretical, fields. For example, evidence has indicated that students' learning performance benefits from instructional material and strategies that accommodate their individual cognitive style (e.g. Duff, 2004; Thomas & McKay, 2010), and from receiving assessment material that in terms of volume, content, and focus is structured to suit their style preference (Evans & Waring, In Press). Similarly, the idea of designing

material that accommodates different cognitive style has received considerable attention within the field of psychology and interaction design (e.g. Ford & Chen, 2001; Graff, 2003)

Within interaction design, researchers (e.g. Houston & Harmon, 2007) have found that hypertext material facilitates performance due to its correspondence with human associative memory structures; that is, our methods of encoding and retrieving information. Individual differences in cognitive style therefore result in differing approaches to computer interaction tasks (Graff, 2003b; 2005; 2006). This idea gave rise to the so-called 'matching hypothesis', based on research findings showing that matching the structure of learning material to the individual user or learner's cognitive style leads to improved performance (e.g. in terms of recall) compared to when there is a 'mismatch' between learner and material (Bajraktarevic, Hall, & Fullick, 1996; Graff, 2003a; 2003b; Liegle & Janicki, 2006). Individuals with a wholist bias recalled the content of hypertext documents better when the hyperlinks were arranged in hierarchical, tree-like fashion. Those with an analytic bias benefited more from a linear hyperlink structure, much similar to moving from page to page in a book. In the 1990s, expectations were that these

findings would have strong implications for the development of instructional material, particularly for distance learning (Graff, 2009). Although some work is still being carried out aiming to produce flexible interfaces to accommodate individual users' cognitive style (e.g. Papanikolaou, Mabbott, Bull, & Grigoriadou, 2006), a lack of replication and contradictory findings (e.g. Calcaterra et al., 2005; Fiorina, Antonietti, Colombo, & Bartolomeo, 2007; Ford & Chen, 2001) has resulted in the matching hypothesis having become more or less abandoned as a research avenue. Brown, Brailsford, Fisher, Moore and Ashman (2006) used individuals' cognitive style to provide personalised content and hyperlink structure in a web-based learning environment. When comparing groups of matched and mismatched students they found no significant differences in performance on an examination given after two weeks of revising the presented material.

A different approach to examining the influence of cognitive style on use of electronic material, rather than seeking to find a way to match content and structure with style, is to focus on the impact of role styles on searching and reading information. In the case of hypertext navigation, it has been

argued that the freedom associated with the non-linear structure of the material allows users to employ their own search strategies resulting in a navigation pattern that mirrors their own cognitive characteristics (Calcaterra et al., 2005), and also that cognitive styles can be inferred by analysing navigation behaviour (e.g. Chen & Liu, 2008).

Analysis of navigation trajectories is commonly employed as a means to developing an understanding of the effects of cognitive style on behaviour and performance with hypertext systems (McEneaney, 2001). Using indices such as time on task, time taken per node, nodes revisited, and types of navigation aids chosen, studies have demonstrated that wholists and analytics differ in terms of navigation speed, and tend to choose different paths through a hypertext system. (e.g. Chen & Macredie, 2001; Chen, 2002; Dufresne & Turcotte, 1997; Graff, 2005; Palmquist & Kim, 2000; Somyürek, Güyer, & Atasoy, 2008).

Several studies have examined navigation path structure in relation to cognitive style (e.g. Dufresne & Turcotte, 1997; Lee, Cheng, Rai, & Depickere, 2005; Reed, Oughton, Ayersman, Ervin, & Giessler, 2000), the general assumption being that field independent and analytic individuals prefer a structured,

systematic path and field dependent and wholist individuals prefer a random, less systematic path. Dufresne and Turcotte designed two versions of a web-based program teaching students to use Microsoft Excel, one non-linear (hierarchical hyperlink structure) and one linear (restricted structure). Measured by the Group Embedded Figures Test (GEFT: Witkin et al., 1971), findings indicated that field dependent individuals performed better with the linear format, and field independent individuals performed better with the non-linear format. They explained this by field independent individuals having a higher ability to engage in independent learning and think analytically, and field dependent individuals being passive and less capable of independent learning. Similarly, Lee et al. examined performance in linear and non-linear information structures and found that field independent students who used a hyperlinked system with the non-linear structure, spent more time to complete the tasks than those who used the system with a linear structure. In all three studies it was found that field independent individuals generally performed equally well regardless of the structure of the material, and that a non-linear material had a detrimental effect only among field dependent individuals. These studies, all

based on the field dependence-independence framework to conceptualise and measure cognitive style, seem to indicate that the field independent cognitive style is more suited to non-linear, hyperlinked environments. Individuals with a field independent bias can make more efficient use of the material and outperform those with a field dependent bias on tasks that require navigating material laid out in a non-linear fashion, such as websites. It seems to support the matching hypothesis, but on a deeper level the findings (and the researchers' interpretations) do not fit with the theory of cognitive styles as bipolar and as a concept separate from ability.

Cognitive Styles and Prior Knowledge

A number of studies (e.g. Calisir & Gurel, 2003; Calisir et al., 2008) have examined the role of experience and prior knowledge in interacting with hypertext systems. According to Spires and Donley (1998), experience determines how an individual organises a conceptual structure and the accuracy of their mental model. Cress and Knabel (2003) manipulated prior knowledge of participants navigating a hypertext system by exposing them to content previews. The previews did not influence navigation strategies, but they did result in a significant

increase in knowledge about the presented topic (as measured by a multiple choice questionnaire), and also affected the participants' evaluation of the hypertext system (previews resulted in more positive views).

Novices' mental models are disorganised, and the accuracy of the mental model (e.g. the hierarchical structure of a website) increases with experience. For example, research has shown that level of experience is related to degrees of disorientation when navigating hypertext systems (e.g. Amadiou et al., 2009). It has also been found that users with prior knowledge of a hypertext structure tend to navigate using depth-first strategies, whereas novices often try to gain an overview by using breadth-first strategies (Jenkins, Corritore, & Wiedenbeck, 2003).

Reed et al. (2000) used a hyperlinked environment consisting of a set of HyperCard stacks on the topic of life in the 1960s, recording individuals' trajectories through the cards. Cognitive style was measured in terms of field dependence-independence as measured by the GEFT. Results showed that field independent individuals took linear paths (sequential forward movement), whereas field dependent individuals took non-linear paths (branching out, skipping steps). This can be

interpreted more as an expression of path length, rather than path 'type'. Field dependent individuals took longer to complete the task, but proportionately, there was no effect of cognitive style on linear/non-linear steps taken; the percentage of non-linear steps was equal for the different cognitive styles. Results also showed that those with more computer experience (measured in years) and programming expertise took more linear steps, whereas those with more experience with hypertext and word-processing took more non-linear steps. Reed et al. did not examine whether there were any interaction effects between style and experience, so conclusions can go no further than observing there is an apparent similarity between the navigation behaviour of field independent individuals and those with high levels of general computer experience.

Using the GEFT, Palmquist and Kim (2000) measured the influence of cognitive style on navigation behaviour within a website. They quantified performance by path length (number of pages visited) and time on task. A sample of undergraduate students were given the task to navigate a university website to find information relevant to career choice and applying for graduate studies. It was expected that field dependent

individuals, due to their global approach, would potentially be more easily distracted by irrelevant material and thus would be less efficient at solving the task than field independent individuals. However, findings showed that this was only the case among field independent individuals with little prior experience of using hypertext material.

Ford and Chen (2000) also examined the role of cognitive style in navigation behaviour, but using the CSA. In general, their findings showed that individuals with a wholist bias tended to make more use of the sitemap and spend more time browsing the higher (more global) levels of the hyperlink structure. In contrast, individuals with an analytic bias made greater use of the site index, spent more time on the deeper, more detailed levels of the hyperlink structure, and made greater use of the back/forward button (resulting in a linear movement through the website). The website used in the study was built around a course in writing webpages using HTML, and the results also included performance on a multiple choice test about how to construct a webpage. No relationships were found between cognitive styles and learning outcome overall, or between browsing strategy and learning outcome. In addition, prior

experience, in terms of domain knowledge (of the subject matter) was measured. A positive relationship was found between prior knowledge and performance; however they also found a positive correlation between style and prior knowledge, with analytic bias being related to greater levels of prior knowledge.

The literature does, however, not fully support the claims of there being a connection between cognitive style, performance and navigation behaviour. Liu and Reed (1994) compared the learning outcome of a group of field independent and field dependent college students using hypertext-based course material, and reported no significant correlation between style and performance. Instead, performance outcomes were related to search strategy, suggesting that the different groups simply employed different strategies in accomplishing the same task. This lack of a connection between learning styles and achievement was confirmed by Wilkinson, Crerar, and Falchinov (1997).

Somyürek, Güyer and Atasoy (2008) used the GEFT to assess field dependence-independence cognitive style of a sample of university students. They also grouped their sample into high and low levels of prior domain knowledge, though it is unclear

how they measured this variable. The task was to navigate a hypermedia-based instruction program teaching the use of Microsoft Word. Navigation measures included linearity, number of different pages, and revisitation. Results showed there was no influence of style on linearity. However, the group they termed 'field intermediate' (i.e. no particular style preference) visited a larger amount of pages, and made more revisits than the field dependent and field independent groups. They also found that the low prior knowledge group made more revisits, and generally visited more pages. These results suggest that not having a clear strategy (field dependent or independent) is detrimental to navigation performance, rather than one strategy being more appropriate than the other. Furthermore, the findings seem to indicate that prior knowledge may be of more relevance to navigation more strongly than cognitive style, perhaps 'overriding' the influence of style on behaviour.

Calcaterra and colleagues (2005) provided a more integrated view of the connection between cognitive style and experience. Using a sample of university students, computer experience was measured by frequency of use and perceived skill levels, and cognitive style was assessed using the Style of

Learning and Thinking questionnaire (SOLAT: Torrance, 1988). The SOLAT is not a measure of cognitive style in the sense that it is not a test of style-relevant behaviour (such as disembedding); rather it is a self-report questionnaire differentiating between 'left and 'right' modes of thinking, the characteristics of which resembles the WA continuum. Left style is associated with analytical thinking and a preference for systematic, sequential information processing; right style refers to wholist thinking and a preference for parallel, global processing. The hypermedia-based material focused on the Mayan civilisation, and contained various types of media (text, images, and videos). Navigation performance was measured in terms of time on task, mouse movements, zooming, perspective change, and revisiting previous sections. Learning performance was measured in terms of a set of information recall tasks and a diagram representing the structural organisation of the acquired information. Results indicated that cognitive style had no impact on time on task and learning. It did, however, to some extent influence the navigation paths; 'right' style thinkers tended to go for depth first, starting lower in the link hierarchy and navigating back to the Introduction section later, whereas 'left' thinkers were more

systematic, starting with the Introduction before moving further down into the structure. Findings also showed a strong influence of experience levels and perceived skill levels on time on task and navigation efficiency, and of navigation efficiency on learning outcomes. The findings suggest that although style may have an effect on navigation strategy, it does not influence navigation performance, at least not as strongly as skill levels associated with prior knowledge (as in in Somyürek et al.'s (2008) study) and experience.

Although it is difficult to draw any firm conclusions about the relationship between cognitive style and navigation behaviour and performance based on the above studies, it would seem that the influence of style is somehow mediated by prior knowledge, either in terms of domain knowledge or exposure to the technology. Ford and Chen (2000) interpreted this as analytic individuals being 'drawn' towards certain types of subject areas (e.g. computers) giving them an advantage over wholists, whereas Palmquist and Kim (2000) interpreted the lack of difference in performance among individuals with high levels of prior knowledge as a result of wholist (or field dependent) individuals having developed strategies to overcome any

difficulties they may have with the material. Although less obvious than in the studies by Dufresne and Turcotte (1997) and Lee et al. (2005), in both cases it essentially assumed that one group, or one end of the style continuum, would be at a disadvantage when using non-linear hypertext material. Somyürek et al.'s (2008) findings and conclusions are to some extent in line with Palmquist and Kim's, in that no conclusive evidence was found suggesting style is relevant to navigation performance. The authors put the lack of an influence of style on navigation patterns down to the 'breadcrumbs' and index tool which could have provided sufficient structure for field dependent individuals. Calcaterra et al.'s (2005) results suggested that prior knowledge level, unlike cognitive style, influenced navigation patterns, which in turn had an effect on learning outcome. In sum, it appears that while cognitive style may have a, perhaps moderate, effect on hypertext navigation, it does not affect the outcome of tasks carried out within hypertext environments. It is therefore necessary to make a clear distinction between measuring navigation behaviour and measuring the outcome of the behaviour. The present research will include measures of both navigation behaviour and performance, and

will distinguish between the two when exploring the impact of cognitive style on hypertext navigation.

3.2. Study 1: Reliability and Consistency of ECSA WA

This study assessed the test-retest reliability, internal consistency and face validity of the ECSA WA measure of cognitive style. Face validity was assessed by asking participants to give an evaluation of the outcome of the ECSA WA relative to their subjective opinion of their own cognitive style. The aim of the study is to determine the robustness of the ECSA WA as a tool in order for it to be included in further studies.

Concerns have been raised whether there is a conceptual overlap between field dependence-independence and cognitive skills, such as intelligence and spatial ability (e.g. Cooperman, 1980; Farr & Moon, 1988; MacLeod et al., 1986; McKenna, 1984). The choice of the CSA (Riding & Cheema, 1991) or the Extended-CSA (E-CSA WA: Peterson, Deary, & Austin, 2003b) for measuring cognitive style in the present research is based on the observation that it is the measure currently closer to being ‘overarching’, encompassing aspects of many of the other style labels. The CSA has also been used in research on performance on computer tasks, in particular computerised learning environments (Chen & Chen, 2002; Graff, 2006; Graff, 2003b; Riding & Grimley, 1999). Whereas the CSA measures cognitive style on a continuum with two value-equal poles (wholist and

analytic), the EFT measures field dependence as a unipolar construct in the same way as skills are measured. To illustrate this, Figure 4 shows an example of an analytic item from the CSA. This is the same type of item used in the EFT, and tests participants' ability to disembed a simple figure from within a complex figure. The EFT consists only of items of this type, and as such measures disembedding skill. In contrast, the CSA also contains items measuring the opposite end of the continuum, testing the participants' ability to recognise global shapes. Figure 5 shows an example of a wholist item. Because of this, the CSA, and more recently the ECSA WA, as a test more accurately measures cognitive style as proposed in the various style theories, namely in terms of manner of performance, rather than level. In other words, neither end of the wholist-analytic continuum is considered better overall. Viewed within the wholist-analytic framework, the EFT only measures the extent to which a person is analytic.

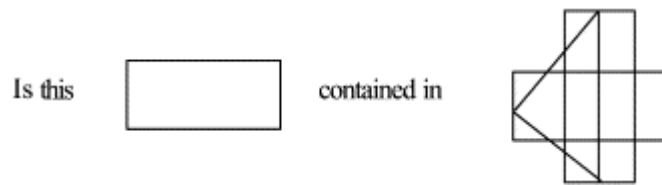


Figure 4. Example of an analytic item on the ECSA WA

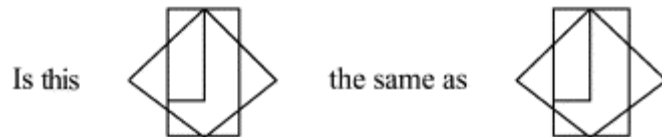


Figure 5. Example of a wholist item on the ECSA WA

The CSA was designed on the back of an extensive review of the cognitive styles literature (Riding & Cheema, 1991). The test has, however, been found to be of poor reliability. Rezai and Katz (2004) measured the test-retest reliability of the CSA on three different occasions. On the first occasion, the interval between the two tests was one week ($r = .42$), and on the second occasion the interval was one month ($r = .45$). The third occasion also had a month's interval between test and retest, but the participants were informed that reaction time was the most important performance factor ($r = .55$). Peterson et al. (2003a; 2003b) tested a sample of university undergraduate students within an interval of six days, and found test a re-test reliability of $r = .30$. In response to the CSA's poor reliability over time,

Peterson et al. (2003a) created an extended version of the CSA, increasing the number of items from 40 to 80. This improved the test's reliability (internal consistency $r = .72$; test re-test reliability $r = .55$).

Although the wholist-analytic dimension is a continuum, researchers (e.g. Graff, 2003) sometimes divide it into groupings and give them descriptive labels based on their position on the continuum. There are three cut-off points of the WA ratio: wholist, intermediate, and analytic. These divisional values are based on mean-based values reported in the original CSA manual (Riding, 1991, 1998).

This study examined the stability of the ECSA WA, by conducting test-re-test reliability examinations. The internal consistency was measured by Cronbach's Alpha using the median response times to the 80 items. The test's face validity was addressed by examining the extent to which the participants agreed with their results, as expressed through a set of rating scales and an open-ended question. Furthermore the stability of cognitive style labels was examined.

Method

Participants

A total of 123 undergraduate psychology students at the University of Leicester took part in the study in return for course credit. The 23 males and 100 females (age range 19 to 38 years, mean 20.23, $SD = 2.43$). To permit examination of the test-retest reliability and internal consistency of the test 46 of the participants took part in the retest some two weeks later.

Design

A correlational design was used. Participants completed the ECSA WA on one or two occasions. The relationship between the ECSA WA scores and four 10-point linear rating scales measuring different aspects of the WA dimension was measured. Furthermore, the relationship between ECSA WA scores and an open-ended question with participants' evaluation of their own ECSA WA scores was measured.

Materials

The ECSA WA (Peterson et al., 2003) contains 40 wholist questions that involve identifying whether or not two complex shapes are identical and 40 analytic questions that involve identifying whether a simple figure is embedded within a more

complex figure. The program presents stimuli in four sets: the 20 original CSA wholist items, the 20 original CSA analytic items, the 20 additional wholist items, and the 20 additional analytic items. The test takes approximately 10 - 15 minutes to complete. Style preferences are measured by comparing their median reaction times to questions about shapes being identical (wholist), with their median reaction times to questions about a single shape being part of a complex figure (analytic), so that each participant is given a wholistic–analytic reaction time ratio which identifies their relative position on a wholistic–analytic style continuum. A low ratio corresponds to the wholist end of the continuum and a high ratio to the analytic. For the wholist stimuli participants are asked ‘Is shape X the same as shape Y?’ (see Figure 5). For the analytic stimuli participants are asked ‘Is shape X contained in shape Y?’ (Figure 4). Half of the items are the same shape or embedded in the more complex figure and half of the shapes are not. The wholist section is completed first, followed by the analytic section. Participants are given feedback (correct/incorrect) on their accuracy after each response.

In addition to the ECSA WA, four 10-point subjective rating scales related to the WA dimension were included. This

was presented on paper. The questions were: 'Do you prefer to look at something as whole or parts?'; 'Do you find it difficult to see the whole or parts?'; 'Do you prefer to have learning material presented in parts or step-by-step?' and 'Do you prefer to have learning material organised by yourself or others?'. Scales ranged from 1 (reflecting a wholist preference) to 10 (reflecting an analytic preference).

An open-ended question was also included, evaluating whether the WA score they obtained was in line with how they perceived their own processing style: "Describe whether you feel your WA score fairly reflects your preferences and behaviour (there are no 'right' or 'wrong' answers – just give your considered opinion based on your score and the position of these within the group distribution".

Procedure

Following the procedure set out in the ECSA WA Administration Guide (Peterson, 2005), participants were told to read and make sure they understood the instructions presented on screen, and respond as accurately as possible and at their own pace. Responses were made by pressing the '1' ('yes') and '2' ('no') keys on the keyboard number pad. For the purpose of the

subjective evaluation question, participants were also instructed to take notice of the result screen at the end of the test, and note down their WA ratio score.

After finishing the ECSA WA, participants were given a booklet containing a brief introduction to the concept of cognitive style and the wholist and analytic characteristics, the rating scales and the open-ended question, which they completed in their own time.

Data Analyses

Alpha was set at .05 and style and rating scale data were treated as interval for the purpose of analysis. The answers to the open-ended question were coded as -1, 0, and 1, reflecting Disagree, Neutral (neither agree nor disagree), and Agree respectively.

Results

Overall mean response times, accuracy and the correlation coefficient for the two sets of wholist and analytic items, in addition to the WA ratios are shown in Table 1. Set A consists of the original CSA items and Set B the additional items.

Table 1. *Overall Means, Levels of Accuracy and Correlations for Wholist and Analytic Item Sets Individually and Combined.*

	Accuracy (Proportion) Mean (SD)	Set A items Mean (SD)	Set B items Mean (SD)	Overall Mean (SD)	Correlation A & B Mean r (p)
Wholist items	.98 (.15)	2.56 (2.83)	2.06 (1.32)	2.31 (2.22)	.63 (<.01)
Analytic items	.97 (.17)	2.06 (1.42)	1.72 (.99)	1.88 (1.24)	.79 (<.01)
WA ratio	.97 (.05)	1.16 (.33)	1.16 (.26)	1.15 (.22)	.25 (<.05)

The internal consistency of the ECSA WA for wholist and analytic items individually and combined was examined using Cronbach's alpha (see Table 2). Inspection of Cronbach's alpha showed that removal of individual items would make little difference.

Table 2. *Cronbach's Alpha for Wholist and Analytic Items Individually and Combined*

	Set A	Set B	Overall
Wholist items	.85	.90	.91
Analytic items	.88	.84	.92

The mean score for the retest was 1.07 ($SD = .17$, ranging from .71 to 1.51) (for test-retest values for the individual items, see Table 3). Pearson's correlation between the test and retest ECSA WA scores was $r = .34$, $p < .05$.

Table 3. *Descriptive Statistics for Mean Response Times and Accuracy for Types of Items (Test and Retest)*

	Mean RT (ms)		Accuracy (proportion)	
	M	(SD)	M	(SD)
Wholist (test)	2.31	1.22	.98	.03
Analytic (test)	1.99	.74	.97	.03
Wholist (retest)	1.97	.74	.98	.03
Analytic (retest)	1.70	.50	.97	.03

Rating Scales and Subjective Evaluation

A significant positive relationship was found between ECSA WA and “Do you prefer to have learning material organised by yourself or others” (Pearson’s $r = .27, p < .05$), indicating individuals with a wholist bias prefer to organise material themselves, and conversely that analytic individuals prefer to have material organised for them. For the subjective evaluation of the obtained ECSA WA scores, 20% of the participants disagreed, 14% were neutral, and 65% agreed (1 score missing). Chi-square test for goodness-of-fit showed the evaluations were not uniformly distributed across the three categories, $\chi^2(2, N = 101) = 45.23, p < .001$.

Stability of Style Labels

Style labels for the initial and retest labels were derived for the WA ratios based Riding’s (1991, 1998) original divisional values. Results are shown in Table 4.

Table 4. *Style Labels for First and Second Test Session*

	Initial label <i>N</i> (proportion)	Retest label <i>N</i> (proportion)
Wholist	33 (.29)	19 (.41)
Intermediate	63 (.56)	23 (.50)
Analytic	17 (.15)	4 (.09)
Total	113 (1.00)	46 (1.00)

Test-retest analysis for style labels revealed a significant relationship, $r = .66, p < .01$.

In order to test for practice effects, paired-samples t-tests were carried out on the response times for wholist and analytic items in the test and retest. Results revealed significant differences between the wholist items (Test 1: $M = 2.31, SD = 1.22$, Test 2: Test 1: $M = 1.98, SD = .74$), $t(104) = 3.57, p < .01$; and also between the analytic items (Test 1: $M = 1.99, SD = .74$, Test 2: Test 1: $M = 1.71, SD = .50$), $t(104) = 6.26, p < .001$.

Discussion

The reliability of the ECSA WA (the 20 additional items) and the items of the test derived from the CSA (the 20 original items) was relatively good. The internal consistency of both sets of items was well above the generally accepted minimum (P. Klein, 1986). Although a very slight increase in alpha was observed, the results suggested the ECSA WA as a whole (in other words, the data sets combined) did not give a substantial improvement in internal consistency. Reliability over time for the ECSA WA was adequate. Support for the face validity of the test was found in that the majority of participants felt their scores accurately reflected their own perception of their cognitive style.

The linear rating scales only partially supported the validity of the ECSA WA in that only one out of four scales were related to cognitive style scores.

Results also showed that the stability of the style labels was high. This finding is consistent with Peterson et al. (2003b) who found a relatively strong test-retest reliability between the wholist and analytic style labels in two sessions six days apart. Furthermore, they found strong split-half reliability in both sessions.

An issue that has been highlighted in previous studies (e.g. Peterson, Deary, & Austin, 2003b; Riding, 1991, 1998) concerning the test-retest interval is that in order to avoid practice effects, a relatively long period of time is required between the two tests. Riding suggests approximately a year. Peterson et al., argued that any practice effects would affect both the wholist and analytic items, making participants respond faster at both sections of the test in the re-test, which would lead to little change in the ratio. Supporting Peterson et al.'s argument, the present results show that practice effects were indeed present, but response times were significantly faster in the retest than the initial test for both wholist and analytic items.

The lack of significant relationships between WA ratio and scores on the three rating scales could be explained by the fact that most of the participants had no strong style preference (the majority of the participants fell in the intermediate style category), and as such their rating could go either way on the scales. The subjective evaluation question did however give some indication of the face validity of the test. A significant proportion of the participants thought their ECSA WA scores reflected how their perceptions of how they preferred to process and organise material.

The findings suggest that the ECSA WA is a robust measure in itself; however the construct validity of the wholist-analytic cognitive style still remains an open question. An important aspect of the validity and usefulness of a test is whether it has a practical application. As Riding (1991, 1998) argued, if a test does not clearly relate to performance, then it cannot be considered to be of any predictive value or substance. The present research will test the practical application of the ECSA WA by examining whether scores on this test relate to aspects of navigation behaviour and performance. As described at the start of this chapter, there is a substantial amount of

research devoted to the influence and relationship between cognitive style and hypertext navigation (e.g. Calcaterra et al., 2005; Chen & Liu, 2008; Graff, 2006; Lee et al., 2005; Liegle & Janicki, 2006; Papanikolaou et al., 2006; Reed et al., 2000). However, due to the variation in cognitive style measures used, these studies do not contribute to strengthening (or weakening) the validity of cognitive style as a construct. The future studies in this research will apply the ECSA WA consistently and also measure it against both behaviour and performance. In light of Riding's theory and previous findings (e.g. Somyürek et al., 2008) it is of particular interest to examine whether style mainly influences manner of performance (in other words navigation behaviour) and is of less relevance to performance.

Another aspect of construct validity is the extent to which cognitive style can be distinguished from other constructs. For example, previous research has demonstrated that style is distinct from personality (e.g. Riding & Wigley, 1997) and intelligence (e.g. Riding & Agrell, 1997). In the present context, it is particularly relevant to determine whether style is distinct from spatial ability, specifically small-scale visuospatial ability. As previously mentioned, concerns have been raised about

whether style is merely a measure of visuospatial ability (e.g. Cooperman, 1980; Farr & Moon, 1988; MacLeod et al., 1986; McKenna, 1984). Although these concerns have mainly revolved around the EFT measure; however it is important to determine whether the ECSA WA is independent of visuospatial skills. This is of relevance to future studies, but also to the interpretation of previous research.

3.3. Study 2: Measuring Hypertext Navigation – A Preliminary Study

This study was primarily designed as an initial exploration of implicit measures of hypertext navigation (hyperlink choice). It also examines whether a relationship is present between cognitive style and their hypertext navigation behaviour (navigation trajectory as resulting from hyperlink choice) and perceived cognitive workload. The relevance of cognitive style in a hypertext navigation situation is assessed, in order to determine whether this measure should be included in further studies.

Research has shown cognitive style is expressed in distinctive navigation patterns (Calcaterra et al., 2005; e.g. Chen & Macredie, 2001; Chen, 2002; Dufresne & Turcotte, 1997; Graff, 2005; Palmquist & Kim, 2000). Findings have also suggested there is association between prior knowledge or exposure and cognitive style when it comes to navigation behaviour. Prior knowledge, in terms of either domain knowledge or frequency of computer use, featured in several of the above studies, but only Calcaterra and colleagues provided some insight into the potential connection between the two variables. To summarise these studies, there is a certain agreement that the interlinked network structure of hypertext environments may be easier to use for individuals with an analytic processing bias. Being required to determine your own navigation trajectory may pose

problems for some individuals. It has been suggested that analytic individuals' systematic and logical progression through the material makes them more efficient 'navigators', whereas wholists run the risk of getting lost and taking longer on navigation tasks (e.g. Chen & Macredie, 2001). Navigation problems notwithstanding, an individual's cognitive style appears to have less impact on task outcome (see e.g. Calcaterra et al., 2005; Somyürek et al., 2008).

Navigation Metrics

Canter, Rivers and Storrs (1985) introduced a method for assessing navigation strategies using two simple indices, which has since been adopted in numerous studies within this area (e.g. Graff, 2005; Palmquist & Kim, 2000). The first is the ratio of the number of different hypertext nodes visited to the number of nodes available in the system, which indicates the proportion of nodes in the system, which are visited by the user. The second index is the ratio of the number of different nodes visited to the total number of visits made to nodes, which gives a measurement of the number of nodes revisited. Table 5 provides a summary of the metrics adopted in some of the relevant studies.

Table 5. *Metrics Used in Studies Measuring Hypertext Navigation*

Study	Parameters
Reed et al (2000)	Linear/non-linear steps (adjacent nodes or not)
Graff (2005)	Number of pages visited, proportion of pages visited, number of pages revisited, depth (lateral or vertical paths)
Calcaterra (2005)	Time on task, mouse movement, revisiting sections, zooming, changing perspective (for images)
Palmquist and Kim (2000)	Time on task, number of nodes visited
Chen and Liu (2008)	Frequency of types of links/tools (e.g. menu, map, index), number of nodes, nodes revisited
Ford and Chen (2000)	Frequency of types of links/tools (map, index), lateral movement (back/forward buttons)
Cress and Knabel (2003)	Number of nodes, number of different nodes, backward navigation, mean display duration of nodes
Somyürek et al (2008)	Linearity (adjacent nodes), number of different nodes visited, number of nodes revisited

Revisiting nodes is taken to be indicative of a narrow focus or localised navigation strategy, and is also taken as an expression of disorientation. A higher amount of revisiting is indicative of an increased likelihood of a user being lost (Herder, 2003; Smith, 1996). Herder made use of a formula developed by Catledge and Pitkow (1997) calculating the probability of a node visit being a repeat of a previous visit:

$$\text{Revisits} = \left(1 - \frac{\text{Different Nodes Visited}}{\text{Total Nodes Visited}} \right) \times 100\%$$

As mentioned above, the influence of cognitive style is more likely to be observed in the ease and manner a task is carried out rather than by measuring performance *per se*. If wholist individuals, who according to the literature are more prone to becoming disoriented (e.g. Lee et al., 2005), have

developed strategies to cope with hyperlinked material, then the role of style can be examined after controlling for experience and by measuring the amount of effort it takes to complete the task. Selecting, processing and integrating information puts high demands on individuals' cognitive resources, potentially leading to disorientation and cognitive overload (e.g. Ahuja & Webster, 2001; Amadieu & Tricot, 2006; Amadieu et al., 2009; Conklin, 1987; Otter & Johnson, 2000). According to Amadieu et al (2009) experience is important because it allows people to use their own mental representation of the domain to guide their navigation and the processing of the content of the concept map, thus making coping with the cognitive demands imposed by hypertext learning easier.

The term cognitive workload refers to the attentional demands experienced during the performance of cognitive tasks (O'Donnell & Eggemeier, 1986). It also refers to people's experiences of cognitive task performance as effortful or fatiguing, which may indicate task demands or attentional overload or underload. Performance deficits may appear when workload exceeds available resources. However, according to Noyes (2001), dissociation is an important aspect of workload

assessment, as it has been found that due to the amount of effort an individual invests in a task, subjectively perceived cognitive workload will increase as performance increases. Various tools have been developed to evaluate and predict cognitive workload, and one of the most widely used is the National Aeronautics and Space Administration Task Load Index (NASA-TLX: Hart & Staveland, 1988). The present study uses the NASA-TLX to measure the cognitive workload experienced when completing a web search task. The NASA-TLX has a number of practical advantages, such as inexpensiveness, ease of implementation, and non-intrusiveness. In addition, it assesses workload on a number of dimensions - comprising the following: mental, physical, and temporal demand, own performance, effort and frustration. Studies have supported its face validity (Tsang & Vidulich, 1994), and it has also been found to be sensitive to changes in objective task difficulty. For example, Haga, Shinoda, and Mitsuteru (2002) found significant relationships between NASA-TLX scores and electrophysiological responses to in the brain (event-related potentials) during a computerised memory search task. Battiste & Bortolussi (1988) reported a test-retest correlation of .77, indicating it is a stable measure.

The present study is designed to examine the relationship between wholist-analytic cognitive style and navigation behaviour. Based on previous work (e.g. Calcaterra et al., 2005) it is predicted that there will be a negative correlation between ECSA WA cognitive style and revisiting rates, indicating that individuals with a wholist bias experience more disorientation. Furthermore, a negative correlation is predicted to be present between workload and style, indicating that a wholist bias is associated with a higher cognitive load. It is also expected that there will be a positive relationship between frequency of use of navigation tools that produce a linear node path ('next' links) and cognitive style, and that there will be a negative relationship between cognitive style and navigation tools that produce a less systematic path (e.g. embedded links).

Method

Participants

44 individuals took part in the study (8 male and 36 female). Age ranged from 16 to 38 years with a mean of 19.61 ($SD = 3.88$). Participants were psychology undergraduate students at the University of Leicester receiving course credits for their

participation and college students from Wyggeston & Queen Elizabeth I College.

Design

A correlation design was used. The variables were navigation performance (number of nodes visited/revisited, and proportion of site visited), hyperlink use, WA cognitive style, workload, and frequency of use (quantified as number of hours spent using computers per week) and confidence was measured on a scale from 0 (not at all confident) to 10 (completely confident). Navigation performance was quantified in terms of total number of nodes (pages) visited; proportion of nodes visited (number of different nodes/total number of nodes *100); and proportion of nodes revisited (1 – proportion of nodes visited). Hyperlink use was measured in terms of number of clicks on links in main menu (left-hand side), sub menu (right-hand side), embedded links (in text), and 'next' links (below text).

Materials

A 'mock' website was produced (see Appendix B for detail about design and coding). The site comprised 56 individual hypertext pages (nodes) arranged in a hierarchy of three levels. The website was built around a standard hierarchical structure

consisting of a main heading across the top (logo etc.), a main menu, a central body text, and additional sub menus. Hyperlinks between topics were also provided within the body text (embedded links). Figure 6 provides a graphic representation of the page layout.

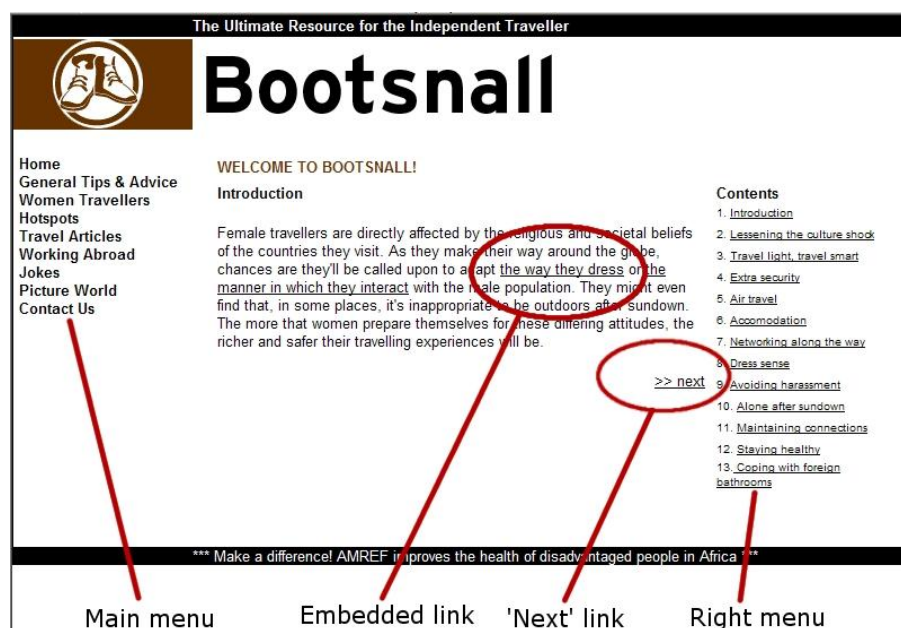


Figure 6. Basic structure of Web page

The main menu contained a single-column table of nine rows; eight with hyperlinks to the main level (Level 1) nodes, and one linked to the home page. Five of the eight Level 1 nodes contained an additional navigation area at the top of the content area, leading to another level (Level 2). For an overview, see Figure 7. The main menu was present throughout the site.

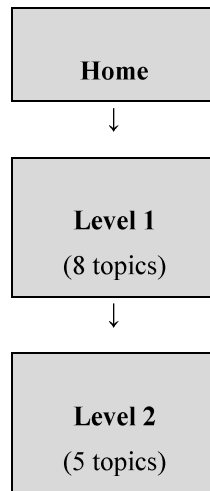


Figure 7. Overview of website hierarchy

The topic for the website was travel. This topic was chosen it was not related to participants' academic course, and thus they were likely to have similar levels of familiarity with it. Furthermore, it was a type of website people are likely to visit through choice (rather than e.g. course work).

Participants were also given 15-item multiple-choice questionnaire with questions based on content of the website (for full version, see Appendix C).

The NASA-TLX (Hart & Staveland, 1988) is a multivariate measure, using six dimensions to assess cognitive workload: mental demand, physical demand, temporal demand, performance, effort, and frustration. Scoring was completed in accordance with the test instructions (see Appendix C for details).

Procedure

Participants were asked to rate their level of experience and confidence, and then completed the ECSA WA according to on-screen instructions. They were informed they would be presented with a multiple-choice questionnaire with questions about the website contents. They were given one minute to familiarise themselves with the questionnaire. They were then instructed to launch the website and start browsing after pressing a 'start' button in the upper right hand corner of the page. They recorded the answers as they went along. Upon completing the task, participants clicked a 'stop' button. This was done to activate/stop the Java-script that recorded the menu clicks and nodes visited. Type of hyperlinks used was recorded by assigning a 'tag' to each node in the HTML code, enabling the researcher to identify which link type was used in order to move between nodes. After the search task participants filled out the NASA-TLX and the multiple-choice questionnaire.

Data Analyses

All statistical analyses are reported with alpha set at .05. Kolmogorov-Smirnov statistics revealed that age and experience were not normally distributed (see Appendix C). Distributions

for number of nodes visited and proportion of nodes visited/revisited were examined. Some of these were not normally distributed; however violations were not sufficient to warrant any adjustments to the data (see Appendix C). Apart from the Physical Demand, Effort and Frustration dimensions, NASA-TLX scores were normally distributed. Inspection of scatterplots indicated no violations of linearity and homoscedasticity (for further details, see Appendix C). Detected outliers were found to have minimal impact on analyses, and therefore retained.

Results

The mean ECSA WA score was 1.11 ($SD = .24$), mean rating for frequency of use was 15.73 ($SD = 8.27$), mean ratings for confidence was 7.46. ($SD = 1.77$), and mean correct MCQ answers was 6.02 ($SD = 1.56$). Mean total workload score was 59.47 ($SD = 15.79$). Means and standard deviations for navigation indices and hyperlink use are shown in Table 6.

Table 6. *Mean and Standard Deviations for Navigation Performance Indices and Hyperlink Use*

	Mean frequency	(SD)
Navigation Pattern Indices		
Number of nodes visited	22.57	(12.16)
Number of nodes revisited	15.07	(14.85)
Proportion of nodes visited	38.91	(14.31)
Hyperlink use		
Main menu	5.89	(4.51)
Submenu	7.64	(7.06)
Embedded	3.34	(3.57)
Next	10.64	(8.08)

Age and Sex

No sex difference was found for hours of frequency of use, mean score for males was 11.88 ($SD = 8.04$) and for females 16.58 ($SD = 8.19$), $t(42) = -1.48$, $p > .05$; or for confidence, mean score for males was 6.88 ($SD = 8.04$) and for females 7.58 ($SD = 8.19$), $t(42) = -1.02$, $p > .05$. Pearson's correlation revealed there was no significant relationship between age and experience ($r = .09$, $p > .05$), or age and confidence ($r = .10$, $p > .05$).

Cognitive Style, Frequency of Use, and Confidence

Pearson's correlation revealed there was no significant relationship between cognitive style and frequency of use ($r = -.18$, $p > .05$), or cognitive style and confidence ($r = -.04$, $p > .05$). A significant relationship was found between frequency of use and confidence ($r = .64$, $p < .001$)

Navigation Patterns

Partial correlation controlling for frequency of use and confidence showed no significant relationships between ECSA WA and the different navigation performance indices (see Table 7). Inspection of zero-order correlations showed frequency of use and confidence had very little effect on the strength of the relationships between the variables (details in Appendix C).

Table 7.

Relationships Between ECSA WA Scores and Navigation Performance Indices Controlling for Frequency of Use and Confidence (Zero-Order Correlations in parenthesis).

	ECSA WA	Nodes visited	Nodes revisited	Nodes proportion
ECSA WA	-	.11 (.13)	-.06 (-.07)	.18 (.21)
Nodes visited		-	.47 (.48)	.82 (.83)
Nodes revisited			-	-.07 (-.04)
Nodes proportion				-

N = 42

Partial correlations were conducted measuring the relationship between ECSA WA and navigation indices. Controlling for frequency of use had little effect on the relationships. Results are presented in Table 8.

Table 8.

Relationships Between ECSA WA Values and Hyperlink Use Controlling for Frequency of Use and Confidence (Zero-Order Correlations in parenthesis).

	ECSA WA	Main menu	Right menu	Embedded links	Next links
ECSA WA	-	-.14 (-.10)	.02 (.07)	-.43 ⁺ (-.36)	.41 ⁺ (.35)
Main menu		-	.64 ^{**} (.64)	-.06 (-.13)	.01 (.00)
Right menu			-	-.16 (-.09)	-.24 (-.26)
Embedded links				-	-.16 (-.17)
Next links					-

Partial correlation showed no significant relationships between ECSA WA scores and total NASA-TLX scores. There was however a significant positive relationship between ECSA WA scores and the performance subscale, and a significant negative relationship between ECSA WA scores and the frustration subscale. Zero-order correlations showed there was little effect experience and confidence on the relationships between ECSA WA and performance ($r = .43, p < .01$), and frustration ($r = -.32, p < .05$). Further details can be found in Appendix C.

MCQ Performance

Pearson's correlation analysis revealed no significant relationships between number of correct answers and hyperlink use or any of the navigation performance indices (details in Appendix X). A significant relationship was found between cognitive style and number of correct answers on the MCQ, $r = .32, p < .05$.

Cognitive Style Grouping Categories

The WA style distribution was skewed towards a wholist bias; mean was 1.11 and according to Riding (1991, 1998; 1991) the majority of individuals are expected to fall in the

intermediate area of the WA continuum. For further investigation it was therefore decided to divide the sample in to Riding's three categories, wholist (≤ 1.02 , $N = 25$), intermediate (between > 1.02 and ≤ 1.35 , $N = 9$), and analytic (> 1.35 , $N = 10$). 3x1 between-groups ANOVAs were conducted examining the effect of style category on the different navigation performance indices. Results revealed a significant effect of style group on proportion of pages revisited, $F(2,41) = 4.09$, $p < .05$, $\eta^2 = .17$. Mean scores for the wholist, intermediate and analytic groups were 1.17 ($SD = .21$), 1.49 ($SD = .56$), and 1.14 ($SD = .32$) respectively. Post hoc tests revealed a significant between the intermediate group and both the wholist and analytic groups ($p < .05$ in both cases), but not between the wholist and analytic groups. No effect was found of group on number and proportion of pages visited (see Appendix B).

3x1 between-groups ANOVAs were also carried out examining the effect of style category on hyperlink use. Results revealed a significant effect of style group on use of 'next' links $F(2,41) = 3.96$, $p < .05$, $\eta^2 = .16$. Post hoc tests revealed a significant between the intermediate group and both the wholist and analytic groups ($p < .05$ in both cases), but not between the

wholist and analytic groups. Mean scores for the wholist, intermediate and analytic groups were 7.88 ($SD = 1.52$), 13.33 ($SD = 2.52$), and 15.10 ($SD = 2.40$) respectively. Post hoc tests revealed a significant difference between the wholist and analytic groups ($p < .05$), but not between the intermediate and wholist and analytic groups.

3x1 between-groups ANOVAs were conducted measuring the effect of style group on the six individual workload dimensions. The only effect to reach a significant level was that of group on frustration levels, $F(2,41) = 3.78$, $p < .05$, $\eta^2 = .16$. Mean scores for the wholist, intermediate and analytic groups were 142.00 ($SD = 101.47$), 183.33 ($SD = 186.70$), and 44.50 ($SD = 56.25$) respectively. Post hoc tests revealed a significant difference between the intermediate and analytic groups ($p < .05$), but not between the intermediate and wholist, and analytic and wholist groups.

3x1 between-groups ANOVA was conducted measuring the effect of style group on the correct responses on the MCQ. Results revealed a significant effect, $F(2,41) = 3.53$, $p < .05$, $\eta^2 = .15$. Mean scores for the wholist, intermediate and analytic groups were 5.64 ($SD = 1.66$), 5.89 ($SD = 1.17$), and 7.10 ($SD = 1.20$)

respectively. Post hoc tests revealed a significant difference between the wholist and analytic groups ($p < .05$), but not between the intermediate and wholist and groups.

Discussion

Results showed there was no significant relationship between WA cognitive style and navigation measures, specifically the amount of pages visited and revisited and the proportion of nodes visited. Contrary to predictions, there was no significant relationship between revisiting of nodes as an indicator of disorientation and WA cognitive style. In other words, it seems that there is no relationship between cognitive style and being prone to 'losing your way'. Controlling for experience and confidence had no influence. However, supporting the hypotheses, it was found that there was a positive relationship between WA cognitive style and choice of hyperlinks. Higher scores (towards the analytic end of the continuum) were associated with more use of 'next' links, suggesting a more linear trajectory. Lower scores (towards the wholist end of the continuum) were related to more frequent use of links embedded within the text, which suggest a more impulsive, less organised trajectory. This does agree with

previous findings (e.g. Calcaterra et al., 2005; Chen & Liu, 2008; Graff, 2005). Contrary to the research suggesting that cognitive style is more relevant to behaviour than task outcome (e.g. Calcaterra et al., 2005; Somyürek et al., 2008), results showed a positive relationship was found between WA style and correct answers on the MCQ. Higher WA style scores (towards the analytic end of the continuum) were associated with more correct answers. No significant relationships were found between cognitive style, confidence, and experience, which appears to contradict the claims that analytics may be more inclined to spend more time on computers (Ford & Chen, 2000).

Due to the distribution of style scores which showed very few participants has landed on the analytic end of the continuum, correlations analyses may not give an inaccurate impression of the relationships. In order elaborate on the findings, it was therefore decided to split the sample into groups according to WA style scores (wholist, intermediate, and analytic). This is not a practice that will be adopted in later studies. Despite the results of the previous study, style labels have been found to be of low stability over time (Riding, 2003); individuals have been found to move between labels, both adjoining labels and from one

dimension to the other. It is therefore be more appropriate to treat WA style as a continuous variable. So, because of the small sample size of the present study and for the purpose of exploration, additional analyses were conducted using discrete style labels. Results showed there was an effect of WA style on disorientation (revisiting nodes). However, rather than wholists being more disoriented as previous research has suggested (e.g. Lee et al., 2005), the intermediate group revisited a significantly higher proportion of nodes than both the wholist and analytic groups. In agreement with the correlation results, there was also an effect of style group on the use of 'next' links. The analytics made significantly heavier use of these links, which indicates a more linear, sequential approach to navigation. Following the correlations it was expected that the wholist group would make more use of the embedded links than the other two groups. Although the data indicated this was a trend, the results did not reach a significant level. A further reflection of the correlation results was the finding that the analytic group reported experience significantly lower levels of frustration with the task compared to the other two groups. Despite the relationship found between style and the performance workload dimension,

there was no significant effect of style group on this variable. In terms of MCQ performance, the analytic group gave significantly more correct answers than the other two groups.

The present study suggests that cognitive style does have some merit in relation to hypertext navigation. Although a clear distinction cannot be drawn between wholists' and analytics' navigation behaviour and performance, the results do show that cognitive style does influence navigation strategies. In particular, the findings suggest analytically biased individuals are more prone to following a stricter strategy, as expressed in their use of 'next' links. The analytics' low level of frustration may also be a result of them being more focused on executing their navigation strategy than the other two groups. This could also contribute to explaining the analytics high performance on the MCQ task. Their strict strategy will have caused them to spend fewer resources on making navigational choices, enabling them to focus more on the website contents.

The wholist group did not show higher levels of disorientation behaviour, which does not agree with previous research suggesting hypertext is less suitable for wholistically biased individuals (e.g. Dufresne & Turcotte, 1997; Lee et al.,

2005; Reed et al., 2000). In fact, it was the individual without a strong style preference (the intermediate group) who displayed the strongest tendency to revisit nodes. This could potentially be a reflection of this group, unlike the wholists and analytics, not having a specific navigation strategy resulting in less efficient navigation.

Based on this study, the ECSA WA is a measure relevant to future studies within this research. Focusing mainly on navigation behaviour rather than task outcome, the present study did not include time on task. Task response times have been found to be affected by style, with analytic bias being associated with faster response times (e.g. Chen & Macredie, 2001; Chen, 2002; Dufresne & Turcotte, 1997; Graff, 2005; Palmquist & Kim, 2000; Somyürek et al., 2008). However, because of the potential conceptual overlap between certain style measures used in these studies (mainly the EFT); it is likely that task response times are more related to tasks that emphasise processing speed, such as visuospatial measures. Future studies will therefore include task response time, but before moving on it is important to examine the relationship between measures of cognitive style and visuospatial ability. The next chapter focuses on the spatial

properties of hypertext and how best to measure spatial ability in the context of hypertext navigation.

Chapter 4

4 Spatialisation of User Interfaces (Study 3)

4.1. Introduction to Topics

This chapter provides the theoretical basis of spatial metaphors necessary for understanding the rationale behind the series of studies presented in Chapter 5. The first part of the chapter describes the emergence of the spatialised user interface, and the type of visuospatial processing required in interacting with desktop-presented environments. In order to examine the conceptual validity of the measures, the chapter includes a study of the relationship between cognitive style, measures of visuospatial ability and sense of direction. The chapter concludes with a discussion of appropriate measures of spatial ability to include in further studies.

The term ‘spatialisation’ refers to the mapping of physical space to abstract domains in user interfaces (Kuhn & Blumenthal, 1996). It is important to note that spatialisation does not refer only to visualised, pictorial information (e.g. desktop icons), but also to spatial relationships (e.g. a file directory). The present research focuses on the spatialisation on hypertext systems, in terms of how hypertext can be embedded in spatial metaphors;

and as such, spatial information systems (e.g. Computer Aided Design environments, Geographic Information Systems) and augmented realities (which make direct, non-metaphorical references to physical space) are beyond the scope of this thesis.

‘Space’ in the context of spatialised user interfaces and spatial metaphors is best understood in terms of experience. Spatialising the user interface taps into people’s need to organise abstract ideas or objects and to ground them in familiar, natural experiences within their surroundings (Lakoff & Johnson, 1980). This refers to both small-scale (figural) and large-scale (environmental) space. According to Montello (Montello, 1993; Montello & Golledge, 1999) the distinction between these two types of space is determined by their size relative to the human body. Broadly, small-scale spaces are characterised by being smaller than the human body and that they can be accessed fully via direct manipulation (e.g. moving, turning). Large-scale spaces exceed the size of the human body, are not directly manipulable, and require the observer to move around to gain full knowledge (e.g. houses, landscapes) (e.g. Rodriguez & Egenhofer, 2000).

Research has suggested that environments presented on desktop systems (e.g. hypertext) may be perceived more as small-

scale stimuli than large-scale environments (e.g. Hegarty & Waller, 2005). Spatial visualisation (small-scale visuospatial ability) is typically measured by tasks that involve perceptually examining, imagining, or mentally transforming representations of small shapes or manipulable objects (e.g. blocks or sheets of paper). Spatial orientation (large-scale spatial ability) tests often involve perspective taking, measuring viewers' ability to make spatial transformations based on their egocentric frame of reference relative to the environment (Zacks, Mires, Tversky, & Hazeltine, 2000). Correlations have been found to be weak between visuospatial abilities and navigation performance in large-scale environments, Hegarty and Waller concluded from their review that visuospatial abilities are important for developing large-scale environmental spatial knowledge. This was based on a study conducted by the authors in 2004 correlating participants' ability to learn the spatial characteristics of a building with small-scale visuospatial tests, tests of general intelligence, and self-reported sense of direction. Although there was no significant relationship between visuospatial ability and performance, results indicated that when controlling for the other abilities, spatial visualisation score was significant predictor of

performance. A more direct relationship has been found between visuospatial ability and learning the spatial characteristics and navigation in electronic environments (e.g. Ahmed & Blustein, 2006; Czerwinski & Larson, 2002; Nilsson & Mayer, 2002)

Dillon (2000) proposed that beyond individual differences in levels of semantic processing users can apply to a hypertext navigation task, there may be differences in users' preference for types of information (spatial or semantic), reflecting their preferred cognitive processing style. Although correlations have been found to be weak between visuospatial abilities and navigation performance in large-scale environments, Hegarty and Waller concluded from their review that visuospatial ability is an important component in the development of large-scale environmental spatial knowledge. In measuring hypertext navigation, the future studies in this research will aim to control for the potential impact of cognitive style and spatial ability. The previous study concluded cognitive style does play a part in hypertext navigation, but that due to a possible conceptual overlap and inconsistent use of cognitive style measure in previous research, this needs to be seen in relation to spatial ability. Furthermore, because it is possible to view hypertext

systems as both small- and large-scale environments (individual pages vs. system as a whole), it is necessary to determine whether there is a relationship between spatial visualisation skills and spatial orientation. The next part of this chapter contains a study examining the relationship between small-scale visuospatial ability, perceived sense of direction, and cognitive style.

4.2. Study 3: Cognitive Style and Visuospatial Ability - A Conceptual Examination

This study examines the relationship between two measures of cognitive style (EFT and ECSA WA), two tests measuring visuospatial ability, and a self-report measure of sense of direction. The objective is to further examine the conceptual validity of the ECSA WA measure, and also to investigate whether the EFT should be considered a measure of visuospatial ability rather than cognitive style. Furthermore, the study examines whether there is a relationship between visuospatial ability and perceived wayfinding skills.

Cognitive style and spatial ability are thought of as two distinct psychological dimensions. While improved ability leads to improved performance, style is dependent on task characteristics. Within the literature there are numerous ways of conceptualising and measuring cognitive style, and some of these may be less conceptually independent of other psychological constructs than others. In the context of hypermedia navigation, one of the most frequently used style measures is the EFT (Witkin et al., 1971) which assesses an individual's position on the field dependence-independence style continuum. The typical finding in these studies is that field independent individuals outperform field dependent individuals (e.g. Dufresne & Turcotte, 1997; Lee et al., 2005; Palmquist & Kim, 2000; Reed et al., 2000); solving navigation tasks faster and using fewer steps. Interesting also is the similarity in navigation behaviour characteristics between

field independent individuals and experts, which could suggest that cognitive style conceptualised and measured as field dependence-independence is not separate from ability.

As mentioned in Study 1, there might be an overlap between field dependence-independence and cognitive processing skills, in particular visuospatial ability. Visuospatial ability is typically measured by skill in performing mental manipulations, such as rotating, flipping or folding two- or three-dimensional objects or shapes. The EFT measures field dependence-independence by ability to identify and isolate a geometric shape inside a larger pattern. According to MacLeod et al. (1986), “even a naive observer could not help but notice the surface similarity of the tests used to measure the two traits” (p. 142). In reviews, McKenna (1984) and Griffiths and Sheen (1992) also concluded EFT scores seem to be indications of visuospatial and to some extent fluid intelligence rather than processing style preferences. In fact, several studies have included the EFT as a measure of spatial ability (e.g. Hegarty et al., 2006; Meneghetti, Fiore, Borella, & De Beni, In Press; Pearson & Ialongo, 1986)

Because the number of studies examining the role of cognitive style in hypertext navigation that conceptualised

cognitive style in terms of field dependence-independence using the EFT, it is necessary to investigate the measure's construct validity. The two issues that need to be addressed are the relationship between scores on the EFT and scores on measures of visuospatial ability, and the relationship between the EFT and the ECSA WA which in Study 1 was found to be a reliable measure of style. The visuospatial measures used in this study are two mental rotation tasks; the Judgment of Line Orientation Test (JLOT: Qualls et al., 2000) and Cooper and Shepard's (1973) mental rotation test; both are based on long research traditions and sound methodology and are easy to administer and analyse. They belong to the same 'family' of tests as those used by Hegarty and Waller in their study on mental rotation and perspective-taking abilities. The JLOT used in this study is a short form Benton, Varney and Hamsher's (1978) original test which is frequently used in clinical and research settings. In order to avoid testing fatigue, Qualls et al. reduced the number of items in the test from 30 to 15, and found scores to be significantly related to the original ($p < .001$) and internally consistent (Cronbach's alpha = .82). The mental rotation test is one of a battery of tests based within a paradigm originally

developed by Metzler and his colleagues (Cooper & Shepard, 1973; Shepard & Chipman, 1970; Shepard & Metzler, 1971) where observers judge whether a pair of asymmetric objects is identical or are mirror images (rotated around standard axes).

In order to comment on whether environments presented on desktop systems (e.g. hypertext) are perceived more as a small scale stimulus than a large-scale environment (e.g. Hegarty & Waller, 2005), the study also examines the relationship between visuospatial ability and environmental spatial ability. Environmental spatial ability is assessed using Hegarty, Richardson, Montello, Lovelace, and Subbiah's Santa Barbara Sense-of-Direction Scale (SBSOD: 2002), in which participants rate their own abilities for navigation and wayfinding tasks. The SBSOD has been found to be internally consistent (Cronbach's alpha .88) with good reliability over time (test-retest $r = .91$), and also significantly related to performance in large-scale spatial tasks ($p < .01$).

In line with the theory of cognitive style and visuospatial ability being separate constructs, it is predicted that there will not be a significant correlation between scores on the ECSA WA and the two visuospatial measures (JLOT and Mental Rotation

Test). Following suggestions that the EFT is a measure of visuospatial ability and not cognitive style, it is predicted that scores on the EFT will be significantly related to scores on the two visuospatial tests, but not to the ECSA WA. Furthermore, in line with Hegarty and Waller's (2004) findings, it is predicted that there will be a significant positive relationship between scores on the visuospatial tests and scores on the SBSOD.

Method

Participants

A total of 34 unpaid undergraduate students participated in the study in return for course credits. The 6 males and 28 females had an age range of 18 to 22 years ($M = 19.03$, $SD = .97$).

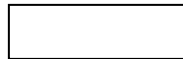
Design

A correlation design was employed. The ECSA WA (Peterson, Deary, & Austin, 2003b) was used to measure cognitive style. Visuospatial ability was measured by a mental rotation task (Cooper & Shepard, 1973) and a short form of the JLOT (Qualls et al., 2000). The EFT (Witkin et al., 1977) was used to measure disembedding skills. Perceived wayfinding skills were measured by the SBSOD (Hegarty et al., 2002).

Materials and Procedure

The study used Set A of the EFT comprising a series of complex geometric designs presented and a number of simple target shapes, both presented on cards. The EFT requires participants to identify a simple shape (such as a cube) within a complex visual array, designed to provide distracting context. An example item is shown in Figure 8. Participants were given one practice trial, and then completed 12 trials. Response times were recorded by the test administrator using a stopwatch.

Here is a simple form we have labelled “X”:



The simple form, named “X” is hidden within the more complex figure below:

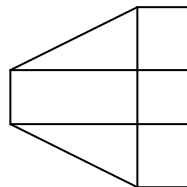
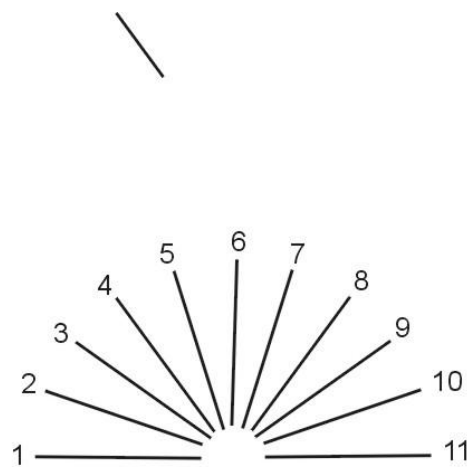


Figure 8. Example item based on the EFT

The short form of the JLOT (Qualls et al. 2000) consists of 15 trials of stimulus and response computerised pictures. The first five items were presented for practice, and these are followed by 15 test items. Each item consisted of a stimulus line

presented above a response-choice array of 11 lines arranged in different directional orientations. Practice stimuli consisted of full-length lines, and the test stimuli consisted of line segments. Each line segment represented either the distal, medial, or proximal segment of a corresponding response-choice line. Answers were indicated by clicking on the number corresponding to the target item. The test was presented using E-Prime software. Figure 9 shows an example item from the test. Accuracy scores were calculated as: correct responses/response time * 10



Which of the lines is in the exactly the same position and pointing in the same direction as the segment shown above?

Figure 9. Example item from the JLOT. The correct answer is line 4.

For the Mental Rotation Test (Cooper & Shepard, 1973) participants were shown an alphanumeric character (letter 'R' or number '2'), then a prompt indicating the direction of orientation

that the letter will appear in when presented as a target (see Figure 10). Following this they were presented with a rotated version of the stimulus and asked to judge whether it is canonical or reflected. Accuracy scores were calculated as: correct responses/response time * 10

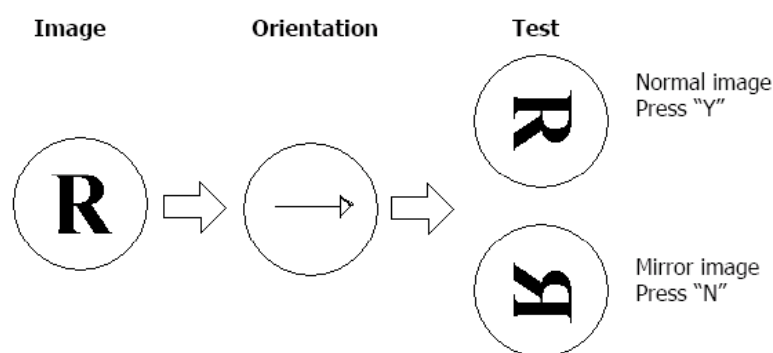


Figure 10. Illustration of the Mental Rotation Test

The SBSOD scale of environmental spatial abilities (Hegarty et al., 2002) consists of 15 Likert-type items where participants are asked to rate their own abilities on navigation tasks. Responses range from 1 (“strongly agree”) to 7 (“strongly disagree”), where low scores indicate strong sense of direction. The full version of the scale can be found in Appendix C.

The ECSA WA (Peterson et al., 2003), described in details in Study 1, was used to measure cognitive style.

Data analyses

Responses were coded according to the information given on the original scales. In all analyses, the alpha level adopted was .05, and two-tailed levels of significance are reported unless otherwise stated.

Results

Means and standard deviations for scores on the cognitive style and spatial ability tests are shown in Table 9.

Table 9.
Means and Standard Deviations for EFT, ECSA WA, JLOT, Mental Rotation, and SBSOD.

	<i>M</i>	<i>(SD)</i>
EFT (RT sec.)	23.21	(41.56)
ECSA WA (ratio)	1.10	(.26)
JLOT (accuracy)	21.7	(.89)
Mental Rotation (accuracy)	87.74	(18.80)
SBSOD (total score)	65.94	(13.81)

Central tendency was determined using the median for the EFT and the ECSA WA. Means were used for the remaining three tests. Table 10 shows Pearsons's correlations for all the variables. Significant negative relationships were present between the EFT and all the spatial ability measures. ECSA WA was not significantly related to any of the other measures, including the EFT.

Table 10.

Relationships (Pearson's r) Between EFT, ECSA WA, JLOT, Mental Rotation, and SBSOD.

	EFT	ECSA WA	Benton Line	Mental Rotation	Sense of Direction
EFT	-	-.26	-.50**	-.58**	-.62**
ECSA WA		-	.31	.19	.18
JLOT			-	.64**	.31
Mental Rotation				-	.38*
SBSOD					-

* $p < .05$, ** $p < .01$

Discussion

Results showed a significant negative correlation between the EFT and all three spatial measures. No significant relationship was present between the ECSA WA and any of the other measures. A small but significant positive correlation was found between scores on the SBSOD and mental rotation, and a significant negative correlation was found between SBSOD and EFT. The SBSOD was not significantly related to the JLOT or the ECSA WA.

The finding that the EFT was not related to the ECSA WA lends support to the concerns put forward by MacLeod et al. (1986), McKenna (1984) and Griffiths and Sheen (1994), in that the EFT does not measure the same construct as the ECSA WA. However, the value of this finding relies upon the validity of the ECSA WA as a measure of cognitive style. Because of the inconsistencies within cognitive style theory, this finding cannot

in itself be taken to imply that the EFT is not measuring cognitive style. However, the EFT was significantly related to measures of visuospatial ability, indicating that being quick at solving the EFT tasks (i.e. having a field independent processing bias), is associated with higher visuospatial skills. This supports the idea that field dependence-independence may be an expression of visuospatial ability rather than cognitive style. Also, the finding that the ECSA WA was not related to the spatial visualisation measures further strengthens the construct validity of the test.

The findings involving self-reported environmental spatial skills showed that a strong sense of direction, as measured by the SBSOD, was associated with a field independent bias and high mental rotation scores. This finding is in line with Hegarty and Waller's (2004) suggestion that high visuospatial ability may be associated with high environmental spatial ability, and adds further support to the idea that the EFT is a measure of visuospatial ability. This finding cannot be taken as evidence for a partial dissociation model of spatial ability as environmental spatial ability was not measured directly, but it does support Hegarty and Waller's (2005) claim that visuospatial ability plays a part in the development of large-scale spatial knowledge.

Some key issues with relevance to the current research arise from these findings. Perhaps most importantly, the theoretical relevance of several of the studies of navigation and cognitive style is questionable (e.g. Dufresne & Turcotte, 1997; Lee et al., 2005; Palmquist & Kim, 2000; Reed et al., 2000). In light of the present findings, these studies have been measuring the relationships and effects of visuospatial ability, not cognitive style, on navigation. This in turn may offer an explanation for findings that suggest one cognitive style (field independent) is 'better suited' for navigation performance in hypertext systems (e.g. Dufresne & Turcotte, 1997; Lee et al., 2005; Reed et al., 2000). Field independence may be an expression of high visuospatial ability, and would as such be associated with improved performance. Furthermore, it can also contribute to somewhat disentangle the complex relationship between cognitive style and experience and the similarities found in the behavioural characteristics of field independent bias and expertise, in that both visuospatial ability and expertise are linked to practice.

Another issue is that because a number of previous studies that have examined cognitive style within the field dependence-independence framework have measured a different construct

than cognitive style as measured by the ECSA WA. The present study suggests it is likely that they may have been measuring spatial visualisation skills; in as far as the EFT is related to measures of spatial visualisation skills. Therefore, in order to explore the impact of cognitive style in light of previous literature, visuospatial ability needs to be accounted for. It is therefore necessary to include at least one of the visuospatial measures included in the present study. The Mental Rotation task belongs to a type of measures within a well-established research tradition (e.g. De Lisi & Cammarano, 1996; Hegarty & Waller, 2004; Jones & Burnett, 2008; Shepard & Metzler, 1971; Vandenberg & Kuse, 1978). Because this measure was related to the SBSOD, it can be assumed that the mental transformations measured by the Mental Rotation task are also involved in the spatial orientation within large-scale spaces. As previously mentioned, hypertext systems contain characteristics belonging to both large- and small scale environments, and on this basis the Mental Rotation task will be included in the future studies.

Chapter 5

5 Studies 4-6

5.1. Mental Models, Metaphor, and Spatial-Semantic Processing

This chapter describes a series of studies investigating the effect of metaphors as a means of conveying the conceptual and spatial structure of a hypertext document. The chapter starts with a description of Padovani and Lansdale's (2003) study, which forms a large part of the theoretical and methodological background for the series of studies. The chapter also focuses on aspects relevant to the individual differences examined in the previous chapter. Following on from Study 3, which identified a relationship between WA cognitive style and navigation trajectory, the interaction between metaphor and the structural layout of hypertext documents (linear or hierarchical) is examined. Furthermore, the effect of task context (search and retrieval) is explored.

There are four aspects of metaphor that are of particular interest to the present research: spatiality, semantic content, prior knowledge, and prototypicality. What these have in common is a link to individuals' mental representations of a metaphor source domain. The series of studies in this chapter has as a starting point a study by Padovani and Lansdale (2003). This study stands out in the navigation literature as it compared directly the effect

of two different metaphors on navigation performance, and in doing so attempted to isolate the effect of one particular aspect, spatiality, relevant to the cognitive processing of metaphors. Furthermore, it brought up an important question concerning what components of metaphor are relevant for users in terms of aiding navigation and recall. Studies 4 to 6 address some of the key questions resulting from Padovani and Lansdale's study. While the main focus is on the effect of metaphor on navigation, the studies also examine the influence of the individual differences (introduced in Chapters 3 and 4), and potential interaction effects between metaphor and task type, and metaphor and hyperlink structure.

Spatiality and Semantics

One of the key areas of investigation in Padovani and Lansdale's (2003) study was the 'spatiality' of metaphors. The metaphors chosen to represent this were a house (spatial) and a social network (non-spatial). Results showed that users were more systematic and faster at navigating in the spatial condition than in the non-spatial condition, suggesting people make use of spatial properties to aid navigation. While the results could be taken as an indicator of the benefits of spatiality, the authors

pointed out that there were important differences in the schematic information available for the two metaphor conditions. When navigating the house website, participants could draw on prior knowledge about how houses tend to be laid out. In the social network no such knowledge was available, which means participants would have to construct their mental representation of the environment more or less 'from scratch'. Therefore, it was unclear from the results if the effectiveness of the metaphors was due to spatiality or prior knowledge.

Another issue was the role of concreteness, or imageability. As established by Paivio (1969; 1971), concepts that are concrete and easily evoke mental images is better comprehended and integrated in memory than abstract concepts. According to Paivio (1971), concrete and abstract concepts are distinguished primarily on "their differential capacity to evoke concrete images as associative reaction" (p. 60). Paivio also proposed that mental images act as "conceptual pegs that link, integrate, and unify memories" (Sadoski & Paivio, 2001, p. 110).

Padovani and Lansdale (2003) made reference to an important aspect of both physical and computer-based environments, in that they are characterised not only by topology

and geometrical relationships, they also contain other information that contributes to giving the space context and meaning. Describing this, Erickson (1990) used the term 'place'. Dillon (2000) used the term information 'shape' referring to a combination of spatial and semantic characteristics. When encountering an information environment users combine spatial properties (e.g. layout, image placement) with semantic attributes of the information (e.g. sequencing, relevance) producing a dynamic knowledge structure, a working schema of the environment. Dillon and Vaughan (Dillon & Vaughan, 1997) claimed topological maps, in terms of connectivity and clustering of spatial landmarks into routes, are insufficient in a hypertext context. Because hypertext structures are also conceptual spaces, the aim of navigation is not merely to arrive at a destination node; users navigate to find information. Dillon and Vaughan's conceptualisation resonates with findings about prior knowledge and navigation efficiency (e.g. Calisir et al., 2008; Chen et al., 2006; McDonald & Stevenson, 1998); when an individual is in possession of both spatial and semantic information about an environment, this leads to a richer mental representation with more information resources that can be exploited to aid

navigation. This is illustrated by a study conducted by Dillon (1991), which examined navigation and comprehension with expert users' of an information space (both print and computer-based) representing a scientific journal article. When participants familiar with the format were presented with selected paragraphs and asked to identify the section to which they belonged (Introduction, Methods, Results, or Discussion), they typically based their decision on both knowledge about the content, and how articles are normally structured. Novices, on the other hand, had to logically infer everything from the text without any reference to expected form or structure. The interplay of semantic and spatial information underlies the development of a dynamic working model of the form and content (shape) of an information environment. Dillon (2000) described the process as spatial characteristics (layout, image placement, length of text, window size, navigation icons etc.) combining with internal representations of the information (i.e. schemata, mental images and models) as well as semantic characteristics of the information environment (expected and actual form, sequencing, meaning etc.), to create a continuously updated and modifiable representation of the information space for this interactive task.

A conceptual representation of the process is presented in Figure 11.

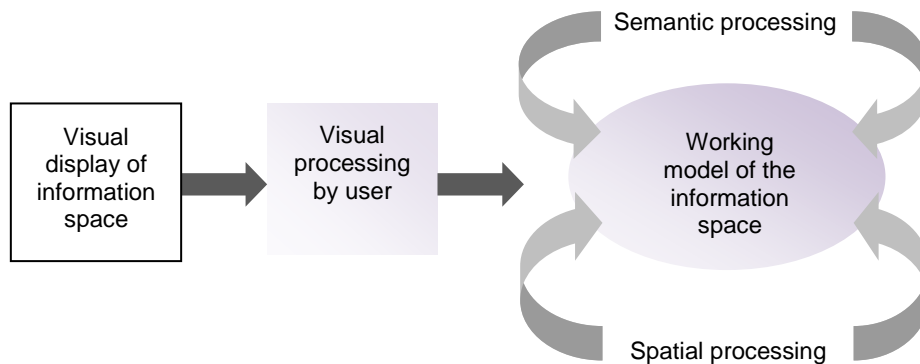


Figure 11. The Spatial-Semantic Model of Shape Perception (Dillon, 2000)

The issue of spatiality and semantics is one of top-down, conceptually based processing versus bottom-up, perceptually driven processing. One of the main purposes of the series of studies described in this chapter is to examine aspects of the extent to which the effectiveness of a hypertext metaphor relies on top-down processing and users' schematic knowledge of prior experience, or bottom up processing where users draw on present stimulus information available on screen.

According to Rosch (1976) the structure of our surroundings has a direct effect on how we categorise objects and experiences. One of the principles underlying Rosch's theory is that of cognitive economy; humans structure the world in terms

of categories in order to get the most possible information out of the environment with minimum effort. Glucksberg and Keysar (1993) described a prototypical metaphor as one that is conventional in a culture and that represents basic concepts. They also referred to the 'goodness' of parts of objects or concepts, in terms of functional significance and perceptual salience. For example, the handlebars of a bicycle are a good part; the bottom bracket is not. This part goodness, according to the authors, is theoretically analogous to the prototypicality of a metaphor. Looking at Padovani and Lansdale's (2003) study, it is likely that the house metaphor has more good parts (e.g. furniture and objects typical for certain rooms) than the town metaphor.

There is substantial literature that shows the value of schematic representation of prior knowledge and experience in memory and learning. According to Alba and Hasher (1983) this type of mental representations provide both a basis for organisation of information and selective attention during encoding of new information, and a plan for accessing stored information during retrieval. Comparing people's ability to form mental representations of familiar and unfamiliar physical environments, Peron, Baroni, Job and Salmaso (1990) found that

there was a significant effect of familiarity on recall accuracy. Participants were able to recall more elements that had been present in a familiar than an unfamiliar area. However, interestingly, the researchers found that recall was poorer for movable elements in the familiar compared to the unfamiliar environment. The researchers attributed this to the idea that items that are not fixed within an environment are not connected with the place schema. This could imply that mental representation performance and based on prior knowledge is more likely to decrease when there are atypical items, or items that do not conform to a schema, within an environment.

Arbuckle, Cooney, Milne and Melchior (1994) examined whether schematic representations of prior knowledge can compensate for the effect of age-related decline in spatial ability when processing spatial information. Arbuckle and colleagues used what they called a schema 'on'/schema 'off' experimental paradigm comparing two groups of younger and older adults' ability to recall house floor plans presented on a computer screen. By moving from room to room using a joystick, participants were required to memorise and recall a floor plan of a typical house (schema 'on'), and a floor plan of a house that did

not conform to layout conventions (schema 'off'). Results showed that the older age group, who scored significantly lower on a test of visuospatial ability, were significantly less accurate in recalling the layout of the schema 'off' floor plan than the younger age group. There are two important implications of these findings: individuals draw on both visuospatial ability and prior knowledge when forming mental representations of an environment; and prior knowledge is increasingly important in situations where spatial information is not readily available, whether it is due to environmental characteristics or decreased cognitive visuospatial processing ability.

5.2. Study 4: Metaphor and Task Phase

As research has shown (e.g. Padovani & Lansdale, 2003), task context needs to be taken into account when measuring user performance. This study was designed to compare and investigate the effect of two different factors on navigation performance, and also on participants' mental representation of the hypertext environment: type of interface metaphor (based on the previous study) and task type or phase (search and retrieval). The study also examines the theory of landmarks (as in salient features) being present in hypertext environments.

One of the main foci of Padovani and Lansdale (2003) was the effect of task phase, (search and retrieval) primarily on choice of navigation aids (bookmarks and sitemaps) and participants' strategies in using these, but also on navigation performance (time on task, number of nodes visited, redundancy, targets found). The overall finding was that the spatial metaphor produced superior performance in both task phases; participants were quicker to complete the search, use fewer steps, were less likely to visit unnecessary screens, and accessed more targets. Furthermore, participants reported carrying out a selective, rather than exhaustive, search in the spatial condition. Although the authors did not directly compare the two task phases, investigation of the ANOVA results suggest there are differences in the navigation patterns in the two phases. The model proposed

for the present research suggests users' familiarity is continuously developing with exposure during interaction; therefore familiarity would increase from the search to the retrieval phase. As part of the rationale for using spatial metaphors is to ease the initial learning curve, it could be argued that any difference in performance between metaphors (spatial vs. non-spatial) will start to diminish in the retrieval phase, as users will have begun forming mental representations of the semantic structure of the non-spatial metaphor in the search phase.

The present study also introduces the mental representation measure chosen for the series of studies in this chapter. One of the most frequently used methods for measuring aspects of mental representations of environments reported in interaction, architecture, geography and psychology literature is map drawing (e.g. Billinghamurst & Weghorst, 1995; Kitchin & Jacobson, 1997; Lynch, 1960). By drawing a map representation of an information environment, individuals can describe how they think concepts are connected and the proximity between pieces of information, either spatially or conceptually. There are several techniques for measuring map representations, and Kitchin and

Jacobson divided them into two general categories; route-based and configurational techniques. Route-based techniques focus on for example retracing routes and estimating direction and distances between route segments. Kitchin and Jacobson identified a number of subcategories of configurational techniques. The two techniques most commonly used within interaction research are graphic tests and reconstruction tests. Graphic tests are variations of sketch mapping techniques, from free drawing and recall, to cued mapping where respondent are given portions of maps and are required to complete specific sections or features. The advantage of using sketch maps is that they give a direct representation of an individual's mental representations of an environment (Taylor, 2005). It has been argued that the map is a good way of conceptualising mental representations as it has an affinity with the connectionist network model of knowledge representation (Sas & Reilly, 2003).

Questions have, however, been raised concerning the potential influence of drawing ability and recall of the individual nodes, rather than the relationship between them (e.g. Taylor). The present research will therefore make use of a partially graphic and reconstruction method. Because the focus is on

testing participants' representations of spatial locations, a spatial cued response methodology (Kitchin & Jacobson, 1997) is appropriate. Using this technique, participants are presented with the relevant nodes, and their task is to place them relative to one another. This provides a structured framework for the responses, and reduces the potential confounding effect of motor skill and drawing ability. This type of task resembles the card sorting often used in usability testing to inform the structure and taxonomy of websites and other material.

In terms of the mental representation and development of spatial knowledge in hypertext environments, there is one aspect of Siegel and White's LRS model (1975) that is of particular interest; the existence and role of landmarks. Golledge (1999) argued that landmarks, both in physical and electronic spaces, can serve both as organising spatial concepts and as navigational aids. Landmarks aid spatial organisation by their role as reference points in an environment. For navigation purposes, landmarks serve as memorable cues selected along a path (particularly in the event of changing direction). Furthermore, they enable coding of spatial relationships between nodes and paths (or in the case of hypertext, hyperlinks), facilitating the

development of mental representations of an environment (Heth, Cornell, & Alberts, 1997). An important aspect of a landmark is its singularity, or prominence, and contrast with the environment (Sorrows & Hirtle, 1999). An example here is the Attenborough Tower on the University of Leicester campus, which with its 18 floors is visible from anywhere on campus (see Figure 12).



Figure 12. The Attenborough Building on the University of Leicester campus.

Sorrows and Hirtle (1999) argued that whereas landmarks in physical environments can be salient features like buildings, landmarks in hypertext are based more on connectivity of a node, or the location of a node within a hyperlink hierarchy. Some

pages may function as landmarks because they contain many links and as such are the starting point for many different actions. They also argue that prototypicality, as described in Section 5.1, may be a feature of landmarks. In hypertext environments, this is associated with for example a prototypical homepage layout. For example, research has shown that users have mental models for typical website layout in terms of for example menu placements and main text body (Oulasvirta et al., 2005), and also distinct mental models for different types of web pages (e.g. shops, news portals) (Roth, Schmutz, Pauwels, Bargas-Avila, & Opwis, 2010). In order to identify landmark nodes, Mukherjea and Hara (1997) proposed three factors that may be of importance; connectivity (number of links in and out of the node), how frequently the node is accessed, and depth (level within site hierarchy). The present study will measure the effectiveness of landmark nodes in terms of correct connections made between these and the adjacent nodes.

With the addition of a town metaphor, the metaphors and experimental tasks are based on Padovani and Lansdale (2003) and findings from the previous study. The tasks are designed to be relevant to each metaphor. Following Padovani and

Lansdale's (2003) findings and conclusions, it is predicted that navigation in the House condition will be significantly faster and more efficient (i.e. shorter time on task and fewer nodes visited) than in the Town condition, and that the Town condition will be faster and more efficient than the Social condition. It is also predicted that levels of disorientation as measured by nodes revisited and perceived cognitive workload will be lower in the House condition than in the Town and Social conditions. Furthermore, based on findings from Study 2, it is specifically expected that WA cognitive style will influence scores on the frustration dimension of the workload measure. In terms of task phase, it is predicted that navigation will be faster and more efficient in the search condition compared to the retrieval condition. It is also predicted that an interaction will be present, in that the difference between search and retrieval will be smaller in the House condition than the Town and Social conditions. It is predicted that mental representations of the House condition will be more accurate in terms of correct connections between nodes, and that there will be significantly more correct connections made from landmark nodes than from other nodes in the system.

Method

Participants

47 individuals took part in the study (15 male and 32) female. Age ranged from 18 to 47 years with a mean of 22.19 ($SD = 5.54$). Participants were psychology undergraduate students at the University of Leicester receiving course credits for their participation.

Design

Participants were randomly assigned to a metaphor condition (House, Town or Social). A 3x2 mixed design was employed to investigate the effect of metaphor (between-groups 3 levels: House, Town and Social) and task phase (within-groups 2 levels: search and retrieval) on navigation. The dependent variables were browsing extent (number of nodes visited), task response time (time on task and average time spent per node), and disorientation (proportion of nodes revisited). Covariates comprised individual's WA cognitive style, measured by the ECSA WA (Peterson, Deary & Austin, 2003); spatial ability measured by the Cooper and Shepard (1973) mental rotation test; frequency of computer use, measured by hours per week; and

computer confidence, measured on a scale from 0 = not at all confident to 10 = completely confident.

Investigating the effect of metaphor on mental representation and cognitive workload, a 3x1 mixed design was used. Independent variable was metaphor (3 levels: House, Town and Social); dependent variables were mental representation accuracy (number of correct connections between nodes on the site map, and number of nodes correctly connected to landmarks), and perceived cognitive workload as measured by the NASA-TLX (Hart & Staveland, 1988).

Materials

The ECSA WA (Peterson et al., 2003b) was used to measure cognitive style and the Cooper and Shepard (1973) mental rotation test was used to measure spatial ability. Perceived cognitive workload was measured using the NASA-TLX (Hart & Staveland, 1988).

Based on Padovani and Lansdale's (2003) original website structure, the website used in Studies 6-12 comprised 29 interconnected nodes with four additional screens containing instructions and task information. This structure was used to build three different versions of the website, each based on a

different metaphor. The general structure is shown in Figure 13. The circles represent nodes, and the arrows represent connections/hyperlinks between the nodes. The numbered nodes are those which contained target items, and along with the nodes containing task instructions (indicated by red colour), these made up the landmark nodes.

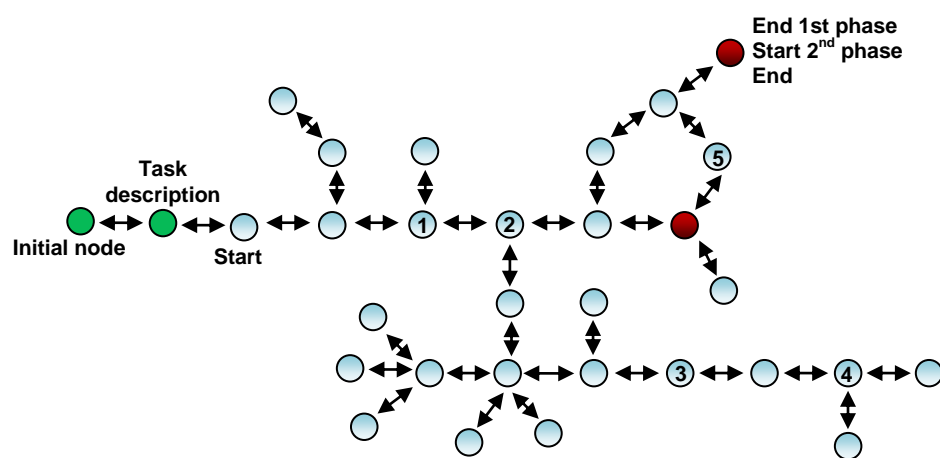


Figure 13. Schematic diagram of website structure (all conditions). Index page and task description are indicated by green circles, and instructional nodes are indicated by red.

Consistent with Padovani and Lansdale (2003), websites were purely textual in order to avoid any graphical differentiation between the nodes. Participants could move by using hyperlinks within the main body of the page or a left hand menu. The website for the spatial familiar condition was based on a house metaphor. Each page represented a room or an external area of the house, and users could move between

adjoining rooms using hyperlinks representing doors or passages between the rooms, or a left hand drop-down menu. In addition to the navigation links, each page contained a brief description of the room's contents and its location within the house (upstairs / downstairs / outside). A diagram of the layout of the site is shown in Figure 14.

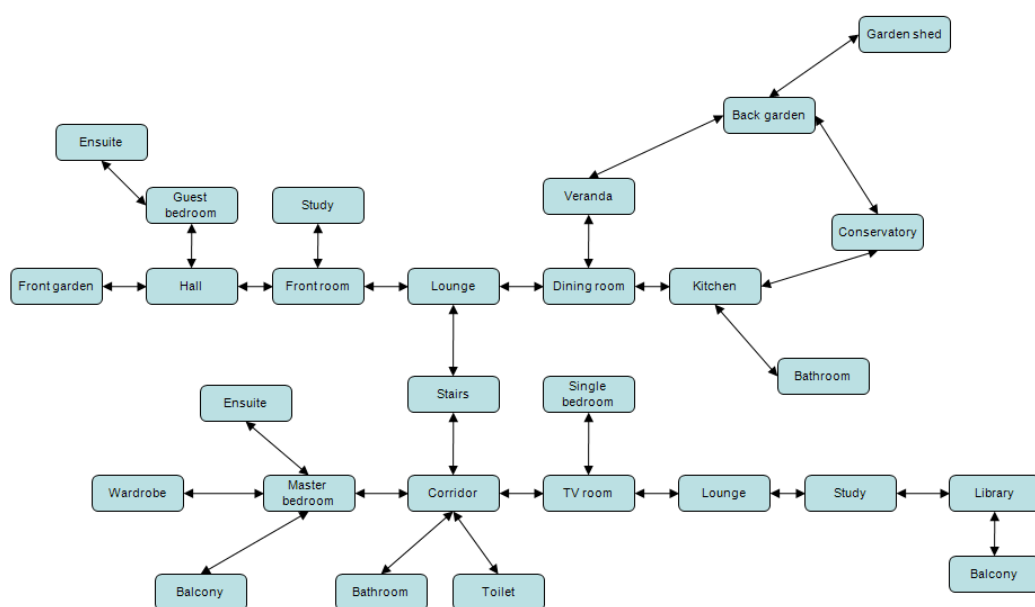


Figure 14. Structure of the website based on a House metaphor

The website for the spatial unfamiliar condition was based on a fictitious town (see Figure 15). In this version each node represented an area, street or building, and the hyperlinks represented passages between the different areas. Each page

contained information about the contents of the area and its location within the town (east end / west end / indoors).

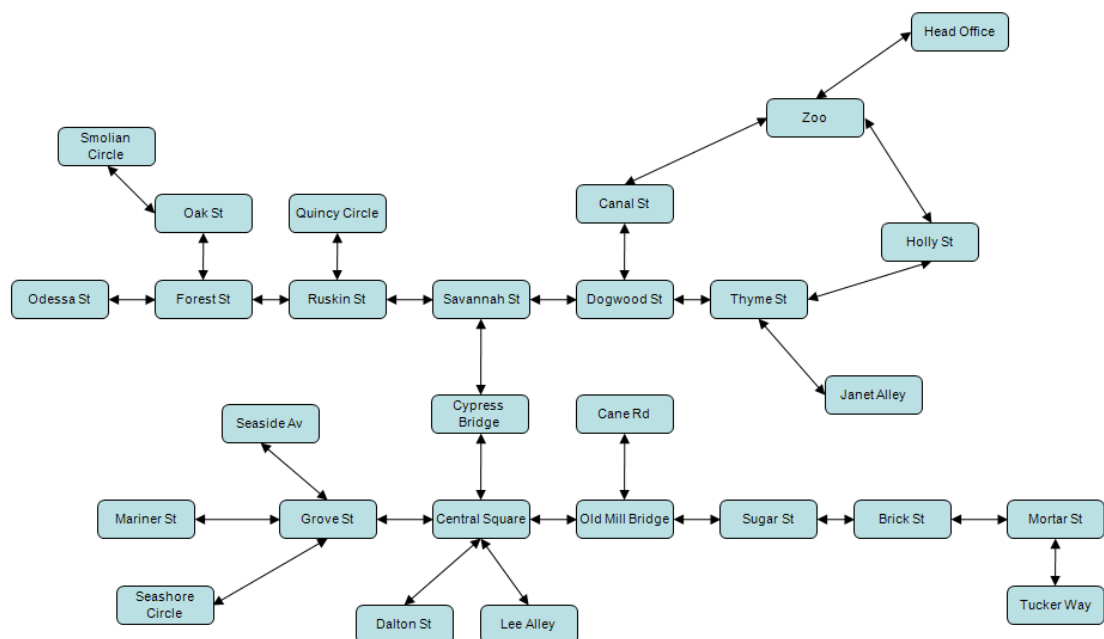


Figure 15. Structure of the website based on a Town metaphor

The website for the unfamiliar non-spatial condition was based on a social network of students (see Figure 16). Each node represented a person, and the hyperlinks represented acquaintances. Each page contained information about the person it represented, and also information about their status (undergraduate / postgraduate / non-academic).

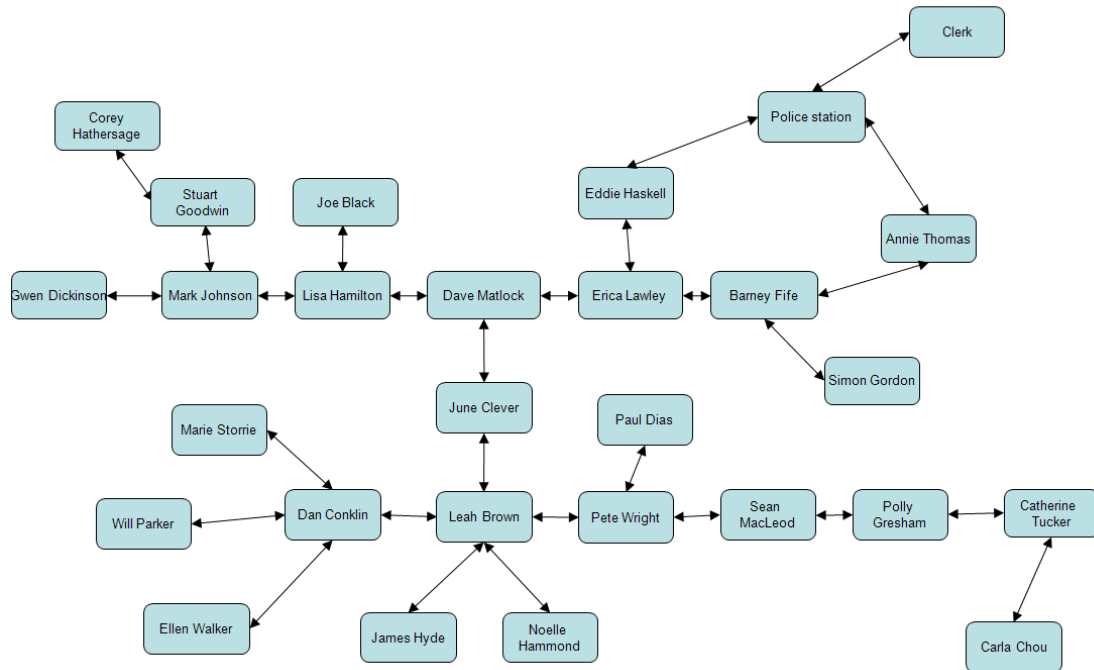


Figure 16. Structure of the website based on a Social metaphor

All three websites were text-based, and contained no graphics other than the drop-down menus (which looked the same for all three websites). Figures 17, 18 and 19 show examples of pages from each of the three websites.

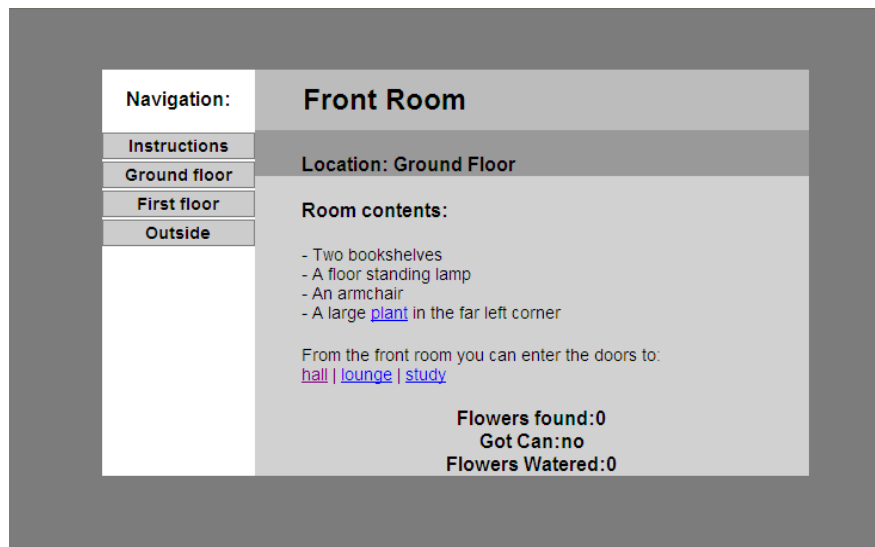


Figure 17. Example of a room in the House metaphor website

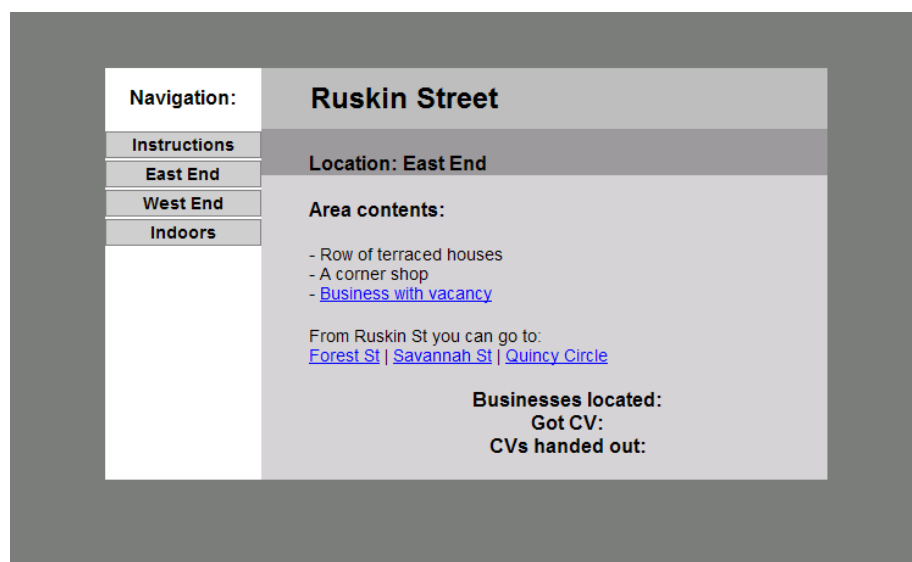


Figure 18. Example of a street in the Town metaphor website

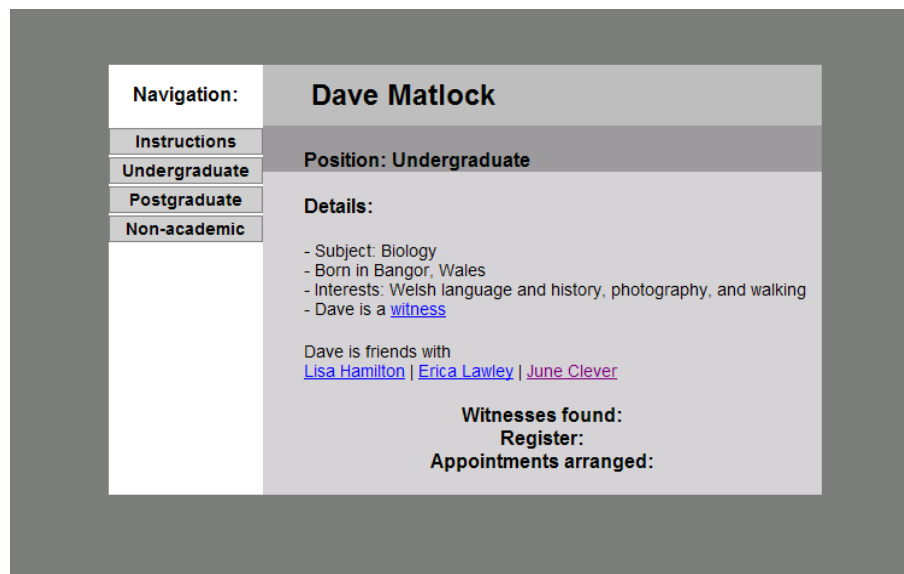


Figure 19. Example of an individual in the Social metaphor website

In order to track the participants' trajectory and number of steps, each node was assigned an individual identity (consisting of a letter/number combination) within the HTML code. A JavaScript was created recording the 'clicks', or visits to the nodes. Cookies were attached to the target items, counting the number of items located, and ensuring the tasks were done in the order specified in the task instructions. A counter was provided at the bottom of the page, keeping track of the participants' progress.

The task was based on that of Padovani and Lansdale (2003) and designed to simulate typical tasks performed by Internet users. It comprised two phases: search and retrieval. The search phase involved locating five target nodes containing specific pieces of information. To complete this phase, participants had to access a predefined node. The same node was

also the starting point for the retrieval phase of the task. This phase involved re-visiting the same five target nodes, and returning to the same predefined node. Although the task structure was the same for all the metaphors, the task description varied to fit each metaphor. In the house metaphor, participants were asked to locate five flowers, retrieving a watering can in the garden shed, water the flowers, and return the watering can to the shed. In the town metaphor, the task was to locate five businesses, make copies of your CV at your office, hand them out at the five businesses, and return to the office. In the town metaphor, participants had to locate five witnesses among a group of university students, take the list of witnesses to the police station, re-visit the witnesses for questioning, and return to the police station. Table 11 shows an overview of the task components for the different metaphors. Point 2 and 5 of the task took place at the same node (Node 11, see Figure 20 for location within the structure). A screenshot of this node is provided in Figure 16.

Table 11. *Task Instructions According to Website Metaphor*

House Metaphor Version	Town Metaphor Version	Social Metaphor Version
According to Mrs Robinson's list your task consists of:	You are looking for part-time job, your task is to:	According to Inspector Smith your task consists of:
1) Finding the five flowers around the house	1) Locate five businesses that have vacancies	1) Locating five witnesses at the university
2) Fetching the watering can from the garden shed	2) Get original copy of your CV from the Zoo Office	2) Registering their names at the police station
3) Filling the watering can (in the kitchen)	3) Make photocopies of your CV (at the Copy Shop)	3) Arrange appointments (with the Student Representative)
4) Watering the flowers	4) Going back to the businesses to give them your CV	4) Returning to the witnesses for interrogation
5) Returning the watering can to the garden shed	5) Return to the Zoo Office your original CV	5) Taking the witnesses' statements to the police station.

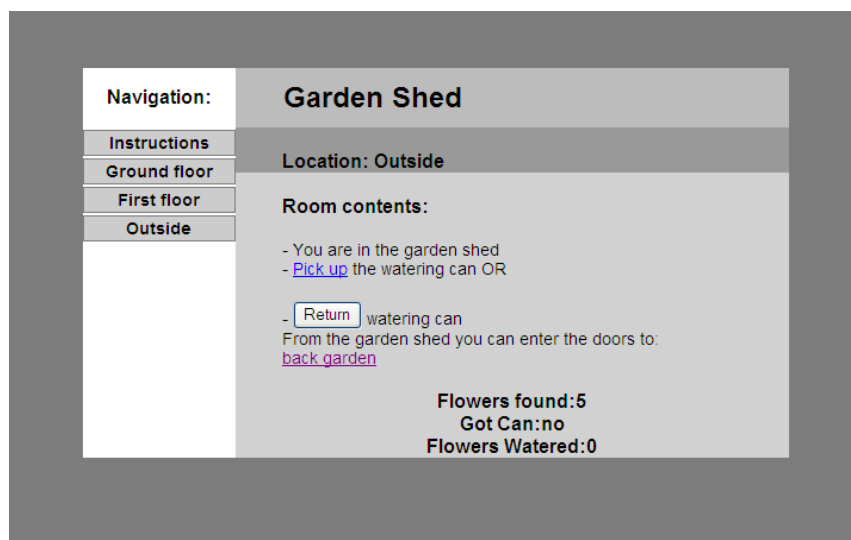


Figure 20. Screenshot of the Node 11 page in the House version

For the sitemap, Microsoft PowerPoint© was used to construct slides containing 29 boxes representing the nodes (see Figure 21). The slide also contained a supply of arrows of different orientation to allow the participants to connect the boxes without having to copy and paste. The maximum number of correct connections for the sitemap as a whole was 28. For landmarks, the maximum number of connections was 12.

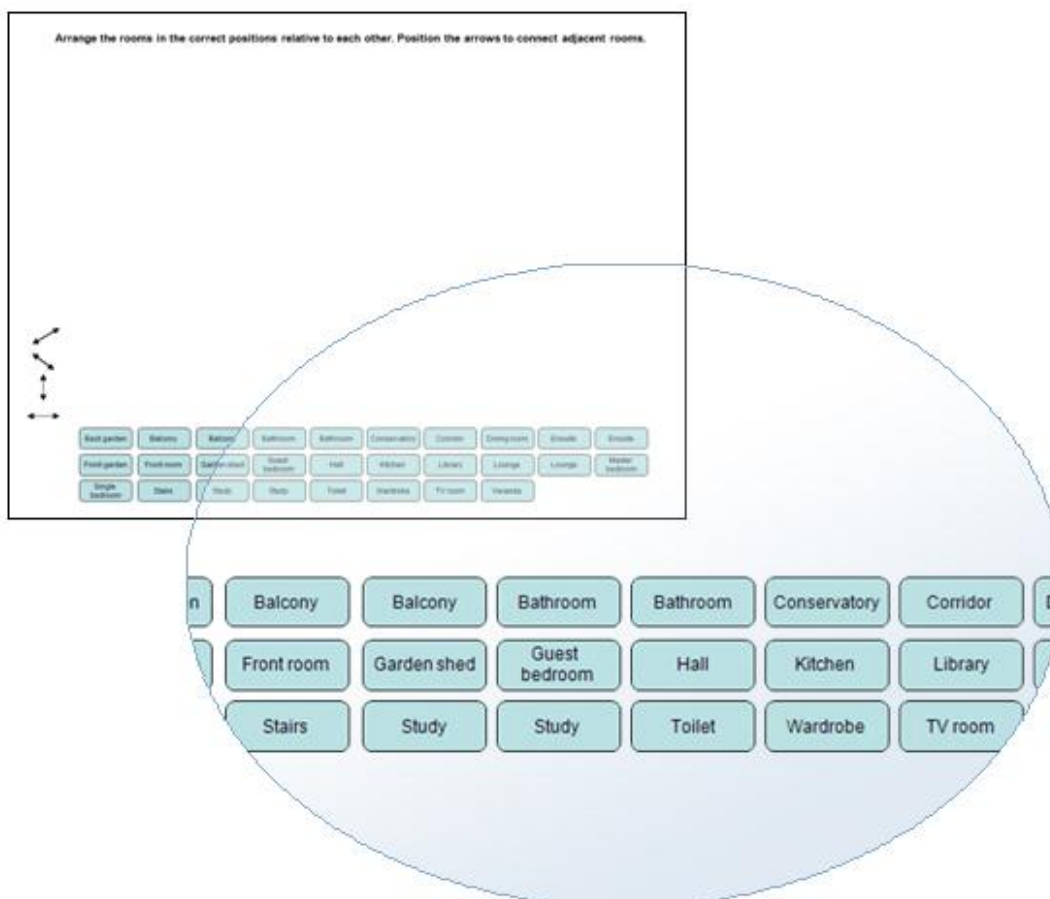


Figure 21. Screenshot of PowerPoint© slide used for creating site map of the House website

Procedure

Participants completed the ECSA WA (Peterson, Deary, & Austin, 2003a; Peterson, Deary, & Austin, 2003b) and then the Cooper and Shepard (1973) test following on-screen instructions. In each version of the website, the two initial nodes contained: (1) a description of the contents of the website and (2) specific, stepwise task instructions.

Participants were informed that the website had the same menu and hyperlink structure and functions as a typical Internet site; and were instructed to read the task instructions carefully and perform the task in their own time. They were able to re-visit the instruction node at any point during the task. A Java-script counter was present at the bottom of the screen throughout the task, informing participants of how many parts of the task they had completed and how many were left to do. A pop-up screen signalled the completion of the two task phases.

After completing the navigation task, all participants were directed to create a sitemap to depict their mental model of the website structure by placing the boxes representing the nodes relative to each other and connecting them using arrows representing links between nodes.

At the end of the session, participants completed the NASA-TLX scale (Hart & Staveland, 1988) to assess the perceived workload experienced during the navigation task.

Data Analyses

Inspection of Kolmogorov-Smirnov statistics for the covariates revealed that the distributions of frequency of use and visuospatial ability were normally distributed. Confidence scores had a kurtosis coefficient of $-.38$, but considering the size and nature of the sample it was judged that the violation was small enough to permit analyses to be carried out. Of the navigation indices, time per node and proportion of nodes revisited in the search phase were the only variables showed a normal distribution, therefore the remaining variables were transformed using a base 10 logarithm, producing more symmetrical distributions. Both sitemap measures (correct connections overall and for landmarks) were normally distributed.

The assumption of homogeneity of variance was violated for the time on task in the retrieval phase, and also for the number of nodes in the retrieval phase. However, because the group sizes are near equal, F is considered robust (Stevens, 2002).

Alpha was set at .05 unless otherwise stated. All scale measures were treated as interval data. Proportion of nodes revisited was calculated as $1 - (\text{number of different nodes} / \text{total number of nodes}) * 100$.

Results

The mean ECSA WA score was 1.23 ($SD = .23$), and the mean score for the mental rotation task was 87.12 ($SD = 26.47$). Participants spent a mean of 14.74 ($SD = 3.60$) hours using computers per week, and their mean confidence score was 7.19 ($SD = 1.42$).

Time

Table 12 shows descriptive statistics for time on task and time spent on each node.

Table 12.
Means and Standard Deviations for Time on Task and Time Spent per Node (sec).

	House (<i>n</i> = 15)		Town (<i>n</i> = 15)		Social (<i>n</i> = 14)		Overall (<i>n</i> = 44)	
	Mean	(<i>SD</i>)	Mean	(<i>SD</i>)	Mean	(<i>SD</i>)	Mean	(<i>SD</i>)
Time on task	150.44	(85.92)	184.92	(88.33)	274.56	(231.89)	201.69	(154.74)
Search								
Time on task	174.11	(57.15)	223.38	(89.17)	267.04	(218.72)	220.48	(139.91)
Retrieval								
Time per node	1.46	(.93)	1.33	(.90)	2.27	(1.53)	1.67	(1.20)
Search								
Time per node	2.35	(.71)	1.63	(.29)	1.81	(.45)	1.93	(.59)
Retrieval								

A 2x3 mixed ANCOVA was performed measuring the effect of metaphor and task phase on time on task. No significant main effects were found. There was no significant influence of confidence, cognitive style and spatial ability, however a significant relationship was found between frequency of use and time on task, partial $\eta^2 = .11$. After adjusting for the covariates, no significant interaction between metaphor and task phase ($p = .46$) was found.

For average time spent per node, a 2x3 mixed ANCOVA showed no significant main effects for task phase. There was a significant main effect of metaphor $F(2,37) = 4.18, p < .05$, partial $\eta^2 = .18$. Post hoc analyses showed a significant difference between House and the other two conditions ($p < .05$), but not between Town and Social. A significant interaction effect was found between metaphor and task phase, Wilks' Lambda = .84, $F(2,42) = 3.52, p < .05$, partial $\eta^2 = .15$ (Greenhouse-Geisser adjusted due to violation of sphericity). There were no significant effects of any of the covariates. Complete results can be found in Appendix D.

Navigation Pattern

Table 13 shows descriptive statistics for the navigation indices (frequency of nodes and proportion of nodes revisited).

All navigation pattern indices were analysed using 2x3 mixed ANCOVAs.

Table 13.
Means and Standard Deviations for Frequency of Nodes

	House		Town		Social		Overall	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Frequency Search	116.80	(56.98)	180.07	(100.52)	135.21	(66.84)	144.23	(80.21)
Frequency Retrieval	81.27	(40.96)	141.20	(60.40)	161.43	(145.18)	127.20	(96.40)
Frequency Overall	209.13	(84.98)	355.40	(98.31)	311.210	(189.37)	291.48	(142.33)

No significant interaction or main effects were found of metaphor or task phase on frequency of nodes visited. There were no significant effects of the covariates. Results are shown in Figure 22.

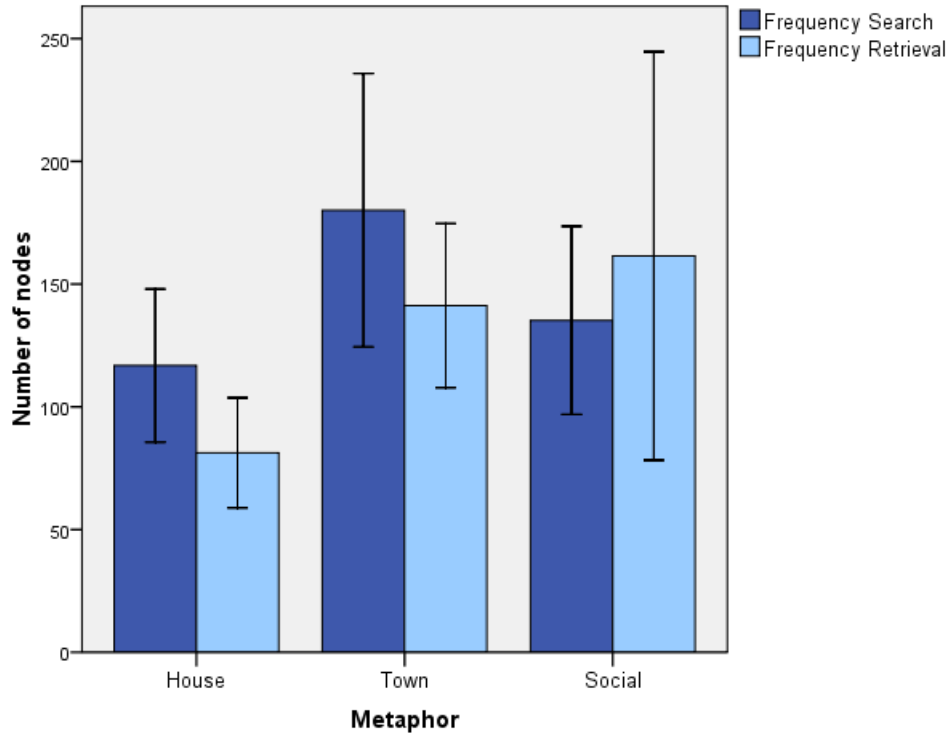


Figure 22. Effects of metaphor and task phase on frequency of nodes visited

Table 14 shows the descriptive statistics for the proportion of nodes revisited in the task overall and during the search and retrieval phase.

Table 14.
Means and Standard Deviations for Proportion of Nodes Revisited

	House		Town		Social		Total	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Revisited Search	71.21	(11.39)	80.99	(7.54)	75.90	10.25)	76.04	(10.46)
Revisited Retrieval	68.86	(8.72)	79.85	(9.54)	76.75	(13.03)	75.08	(11.27)
Revisited Overall	84.80	(4.93)	91.27	(3.28)	88.39	(5.99)	88.14	(5.42)

A significant main effect was found of metaphor on proportion of nodes revisited, $F(2,36) = 5.03$, $p < .05$, partial $\eta^2 =$

.22. Post hoc analyses revealed a significant difference between House and Town ($p < .01$), but not between House and Social, or Town and Social. No main effect was found for task phase, and no interaction effect was present between metaphor and task phase. None of the covariates had a significant effect. Effects are illustrated in Figure 23. For complete results, see Appendix D.

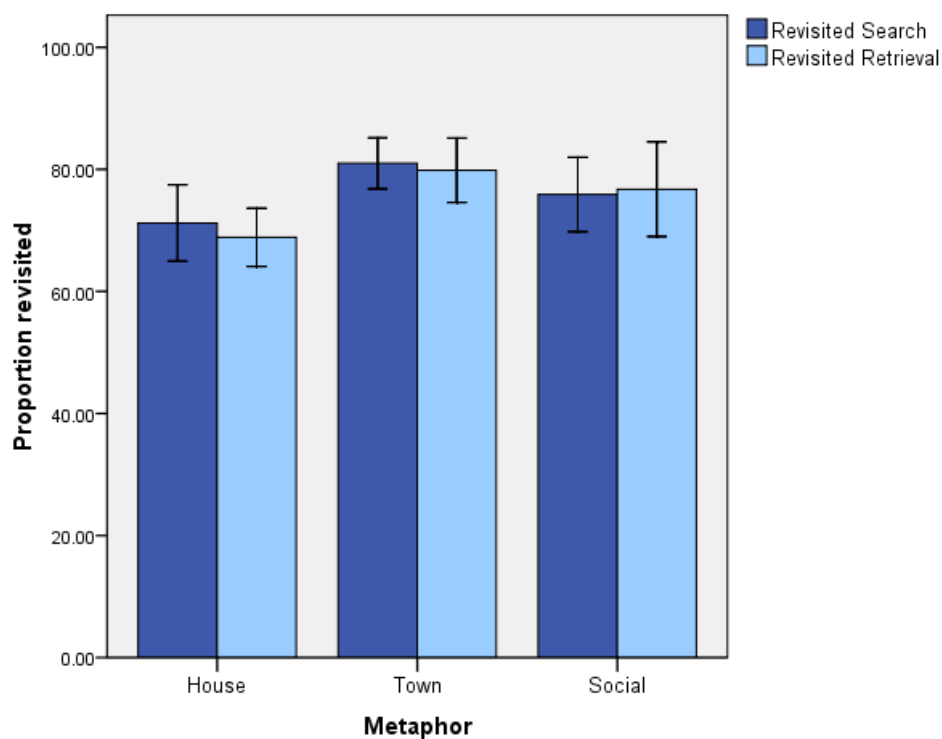


Figure 23. Effects of metaphor and task phase on proportion of nodes revisited

Sitemap

Table 15 presents the descriptive statistics for the number and percentage of correct node connections made in producing the sitemap.

Table 15.

Means and Standard Deviations for Number and Percentage of Total Correct Connections and Correct Connections to Landmark Nodes.

		House		Town		Social		Overall	
		Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Number	Total	14.78	(4.44)	5.89	(3.22)	4.11	(2.98)	8.26	(5.88)
	Landmark	8.00	(2.87)	3.11	(1.45)	3.00	(1.80)	4.70	(3.14)
Percent	Total	52.78	(15.85)	21.03	(11.50)	14.68	(10.63)	29.50	(21.00)
	Landmark	64.81	(19.89)	41.67	(25.93)	25.00	(15.02)	38.58	(24.37)

One-way ANCOVA showed significant effects of metaphor on both connections made overall, $F(2,20) = 13.37$, $p < .001$, partial $\eta^2 = .57$, and landmark connections $F(2,20) = 10.63$, $p < .001$, partial $\eta^2 = .52$. For both dependent variables, post hoc analyses revealed a significant difference between House and Town ($p < .001$), and House and Social ($p < .001$), but not between Town and Social. Results are shown in Figure 24. There were no effects of any of the covariates the sitemap variables.

A paired-samples t-test revealed that the proportion of correct connections made from landmark nodes was significantly higher than the correct connections made from the other nodes $t(26) = 5.10$, $p < .001$.

Pearson's correlations analysis was carried out measuring whether there was a relationship between overall sitemap accuracy and navigation measures in the search and retrieval

phases. Results showed significant negative correlations between total correct connections and: time on task in the retrieval phase ($p < .05$), frequency of nodes in the retrieval phase ($p < .01$), and proportion of nodes revisited in the retrieval phase ($p < .01$). A significant positive relationship was found between total correct connections and average time per node in the retrieval phase ($p < .05$). No significant relationships were found between correct connections and any of the navigation measures in the search phase. A complete correlation matrix can be found in Appendix D.

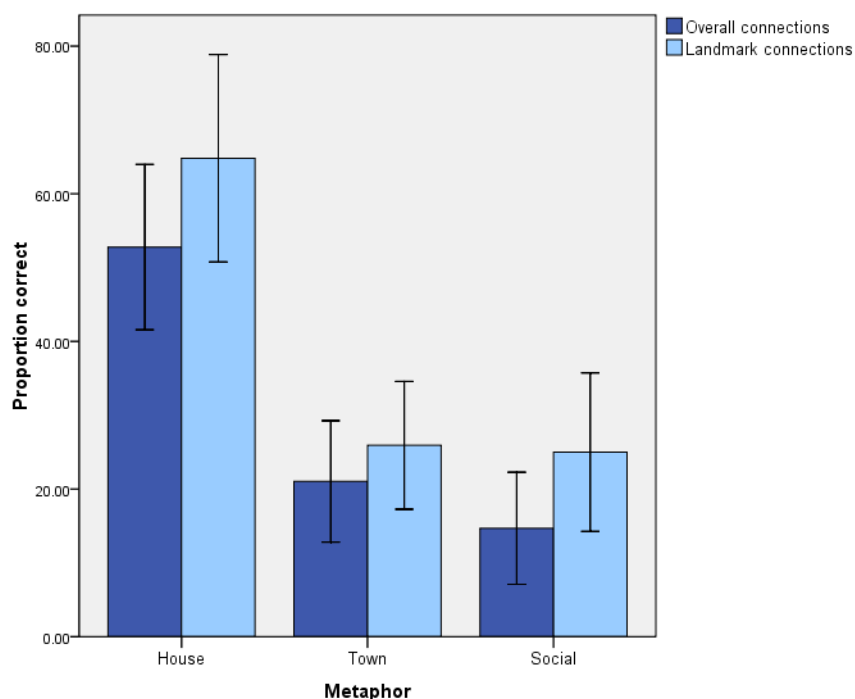


Figure 24. Proportion of correct connections made in sitemap overall, and for landmark nodes only.

Cognitive Workload

Table 16 shows the descriptive statistics for scores on the NASA-TLX, overall and for the different dimensions separately.

Table 16. *Mean and Standard Deviations for NASA-TLX Scores (Overall Weighted Score and for Dimensions Separately)*

NASA-TLX dimension	Mean	(SD)
Overall workload score	65.44	(13.47)
Mental demand	258.83	(149.16)
Physical demand	21.06	(75.38)
Temporal demand	113.09	(94.98)
Effort	140.00	(92.54)
Performance	216.17	(116.60)
Frustration	231.60	(158.60)

A 1x3 ANCOVA revealed there was no significant effect of metaphor on total perceived workload $F(2,40) = .23$, $p = .80$. No effects were found for any of the covariates.

1x3 ANCOVAs were conducted on the six workload dimensions individually. There were no effects of metaphor on any of the dimensions. For the covariates, a significant effect was found of cognitive style and frequency of use on the frustration dimension, $F(1,40) = 8.01$, $p < .01$, partial $\eta^2 = .17$ and $F(1,40) = 3.30$, $p < .05$, partial $\eta^2 = .13$ respectively. For the effort dimension, significant effects were found for cognitive style and visuospatial ability, $F(1,40) = 8.99$, $p < .01$, partial $\eta^2 = .18$ and $F(1,40) = 5.93$, $p < .05$, partial $\eta^2 = .13$ respectively.

Discussion

No significant effects were found of metaphor or task phase for time on task. Metaphor did, however, have an effect on average time spent per node, and an interaction effect was found between metaphor and task phase. In the house condition participants spent more time per node in the retrieval than the search phase of the task, whereas in the Social condition the opposite was the case. In the Town condition participants spent a more or less equal amount of time per node in the two task phases. No significant effects were found for frequency of nodes visited; that is, participants did not visit significantly fewer or more nodes in any of the metaphor conditions or task phases. An effect of metaphor, but not of task phase, was found on the proportion of nodes revisited. Specifically, participants revisited fewer nodes in the House condition than in the other two, in particular the Town condition.

For the sitemap task, participants were significantly more accurate in the House condition than the other two; they made more correct connections from both landmark and other nodes. Also, results showed that overall, more correct connections were made from the landmark nodes than the other nodes. Significant

negative correlations were found between overall correct connections and time on task, number of nodes and proportion of nodes revisited in the retrieval phase; and a significant positive correlation was found between overall correct connections and average time per node. No effects were found of metaphor on perceived workload.

The results suggest participants employed a different strategy in the House condition compared in particular to the Social condition. The tendency to dwell longer at each node in the retrieval phase in the House condition could be an indication of participants having a clearer idea about the location of the different targets, and therefore taking more time before making navigational choices. In the Social condition participants spent more time per node in the search phase than in the retrieval phase. Following research on the value of schematic representations of prior knowledge in relation to decreasing the load on spatial processing (e.g. Arbuckle et al., 1994), it is likely that since participants had little prior knowledge about the layout of the environment in the Social condition, they had to spend more time in the search phase processing spatial information and familiarising themselves with the environment.

The benefit of prior knowledge on performance was also reflected in decreased levels of disorientation in the House condition than the other two. Contrary to predictions, task phase did not significantly affect participants' levels of disorientation in that proportion of nodes revisited did not differ between the search and retrieval phase. A likely reason is that the exposure time was not long enough to allow for significant improvement of mental representations from the search to the retrieval phase.

Controlling for individual differences did not influence results greatly. For the behaviour measures, the only covariate to significantly be of significance was higher frequency of use, which was associated with faster task times. The subjective workload evaluations suggest there was some impact of cognitive style and visuospatial ability on how hard participants felt they had to work to solve the tasks. Cognitive style had an influence on the frustration and effort dimensions. Specifically, a wholist bias was associated with higher levels of frustration and effort. Visuospatial ability had an effect on the effort dimension, in that higher scores on visuospatial ability were associated with lower levels of effort. Furthermore, higher frequency of use was associated with lower levels of frustration. These results suggest

that participants with a wholist processing bias may have found the task more demanding than those with an analytic bias. This is in line with previous research, which has shown that hypertext systems may be easier for people who have a more systematic and focused approach to problem solving (e.g. Dufresne & Turcotte, 1997; Lee et al., 2005). It is interesting to notice that there are no effects of cognitive style on any of the performance measures. This can be a reflection of wholist individuals having learned to compensate for their processing disadvantages, which leads to equal performance as analytics, but at a higher cost.

Another possible explanation for why WA cognitive style did not influence results could be that users had developed schematic knowledge of the typical layout of web pages (e.g. Oulasvirta et al., 2005; Roth et al., 2010) and are able to draw on this regardless of cognitive processing preferences. The finding that lower visuospatial ability was associated with users feeling they had to spend less effort is not wholly surprising. It was expected that there would be an effect of visuospatial ability on the behavioural and performance outcomes, but this did not occur. Again, it is possible that people who were at a disadvantage in terms of cognitive style or ability have learned to

compensate behaviourally, but have to spend more effort doing so.

The sitemap results were in line with predictions. The findings that participants made more correct connections in the House condition than in Town and Social is very likely due to participants having stronger schematic representations of prior knowledge of the typical layout of a house, and were able to draw on this when constructing the sitemap. The finding that there was no significant difference between accuracy in the Town and Social condition was unexpected. Town was based on a spatial source domain and Social was based on a non-spatial source domain, and following Padovani and Lansdale's (2003) findings a difference between the two would have been as expression of the importance of spatiality in metaphor. It is possible the lack of difference is due to spatiality not being a critical aspect of metaphor. However, it could also be argued the House and Town are based on two different types of spatiality. The Town metaphor is based on large-scale spatial properties, whereas the House is smaller-scale. In light of for example theories proposed by Downs and Stea (1977) and Hegarty et al. (2006) and neuroscientific evidence (e.g. Kosslyn & Thompson,

2003; O'Keefe & Nadel, 1978), the spatial scale of the source domain could be of relevance to the participants' processing of the hypertext system. The type of visuospatial ability measured by the Cooper and Shepard mental rotation task is more relevant to small-scale tasks, or what Downs and Stea called perceptual space (rather than large-scale, transperceptual space). The other possibility is that the differences were due mainly to the House being a familiar and prototypical environment, whereas the fictitious Town was not. According to Rosch et al. (1976) and Glucksberg and Keysar's (1993) theories, a prototypical metaphor is typically conventional in a culture, and contains parts that are salient and functionally significant. In the House metaphor, participants would have expected the kitchen to contain a water tap. This would have been of aid in solving the task (filling the watering can). Furthermore it would likely have functioned as a 'conceptual peg' (Paivio, 1971; Sadoski & Paivio, 2001), helping participants build a more accurate sitemap. While the Town may have adhered to cultural conventions, it would have had fewer parts that were of specific functional significance to the task.

The accuracy of participants' sitemaps was negatively correlated with most of the navigation measures in the retrieval

phase. That is, increased sitemap accuracy was associated with increased navigation efficiency; specifically, faster task times, fewer nodes visited and a smaller proportion of nodes revisited. A possible interpretation of this finding is that having a good, accurate mental representation from the outset aids navigation. It is also possible that navigation skills and skill in forming mental representations are related. Increased sitemap accuracy was also associated with spending more time per node. There were no significant relationships present between sitemap accuracy and navigation measures in the search phase. The results suggest differences in behaviour and performance, and the relationship between performance and accuracy did not become apparent until later in the task journey. During the early phase of the navigation task, behaviour was quite similar across the different metaphor conditions, and not indicative of participants' mental representations of the hypertext system. This is somewhat at odds with the idea of metaphors as reducing the learning curve within computer environments (Blackwell, 2006). However, metaphors *did* result in differences in sitemap accuracy after task completion, which could be a reflection of the time it took

participants to integrate and assimilate the metaphors with their existing mental representations of the different source domains.

5.3. Study 5: Metaphor and Hyperlink Structure

This study was designed to examine the effect of hyperlink structure on navigation performance and accuracy of mental representation, as literature (e.g. Lee et al., 2005) has shown this to be particularly relevant in connection with cognitive style. Two types of structures are examined: a hybrid structure (hierarchical and cross-referenced links) and a linear structure. Metaphor is included in the design in order to examine whether there is an interaction between hyperlink (physical) structure and the structure provided by the metaphor source domain.

Research has identified conceptual and theoretical inconsistencies in the cognitive style literature, which makes findings difficult to interpret. A number of studies within the navigation literature have made use of the EFT, a measure that probably assesses visuospatial ability rather than style. Study 4 and the present study address this issue by including both a cognitive style test and a test of visuospatial ability as covariates when measuring navigation performance and behaviour.

It is possible that an interaction may be present between metaphor and cognitive style insofar as both affect how information presented via hypertext is processed. Evidence suggests that individuals with a wholist bias may benefit from having fewer potential distractions and options for 'going off on tangents' when solving navigation tasks (e.g. Calcaterra et al.,

2005; Dufresne & Turcotte, 1997; Lee et al., 2005; Liegle & Janicki, 2006; Reed et al., 2000). Dufresne and Turcotte compared the influence of field dependent-independent cognitive style on disorientation and cognitive load within two different hypertext structures ('restricted' versus 'open'). They found style only influenced performance in the open structure. It was suggested this may have been a consequence of the open structure leading to higher levels of disorientation and poorer performance among field dependent participants, and that these participants struggled to understand and remember the information they encountered browsing freely. Because a wholist bias shares many characteristics with field dependence, this could imply that individuals with a wholist processing bias may do better with hypertext with fewer navigation options and a layout that forces them to move through the material in a more linear manner.

The influence of metaphor in relations to hyperlink structure is not known. Metaphors are intended to help users structure information; therefore, it is possible that imposing a structure through physical layout may interfere with the effects of metaphor or vice versa. Part of the rationale behind interface metaphors is to help users overcome limitations or potential

problems by providing them with metaphoric ‘scaffolding’. Therefore, attempting to further direct users’ navigation behaviour through restricting navigational flexibility can potentially have the opposite effect, hampering performance. However, there is no empirical evidence to support this.

It is predicted that there will be a significant influence of WA cognitive style on navigation behaviour and performance (time on task, time per node, number of nodes visited, and proportion of nodes revisited) and accuracy of mental representations (correct connections in sitemap). Furthermore, it is predicted that there will be a significant positive relationship between WA cognitive style and perceived workload scores (NASA-TLX) in the hierarchical, but not in the linear condition. The study is also designed to replicate the results obtained in the previous study showing that the House metaphor resulted in improved navigation performance and higher accuracy of mental representations.

Method

Participants

91 individuals took part in the study; 17 male and 74 female. Age ranged from 18 to 30 with a mean of 19.48 years (*SD*

= 1.89). Participants were psychology undergraduate students at the University of Leicester receiving course credits for their participation.

Design

A 3x2 between-groups design was used with participants randomly assigned to metaphor (3 levels: house, town, and social) and hyperlink structure (2 levels: linear and hybrid). Dependent variables comprised internal representation, as measured by accuracy of sitemap (number of correct connection between nodes); perceived cognitive workload, as measured by the NASA Task Load Index (NASA-TLX: Hart & Staveland, 1988); browsing extent (frequency of nodes visited), task response time (time on task and average time spent per node), and disorientation (proportion of nodes revisited). WA cognitive style and visuospatial ability were included as covariates.

Materials

Materials comprised the ECSA WA (Peterson et al., 2003), and Cooper and Shepard's Mental Rotation Test (1973). The same website was used as in previously, with the addition of a linear version. The linear version was identical to the original hybrid website with regards to content and structure. However, whereas

the hybrid sites gave participants the choice between using direct links between adjacent nodes and using the left-hand menu to jump between nodes; the linear sites did not have left-hand menu, thus making a linear movement between adjacent nodes the only possible navigation trajectory. Figure 25 and Figure 26 show examples of nodes within the linear and hierarchical versions of the House.

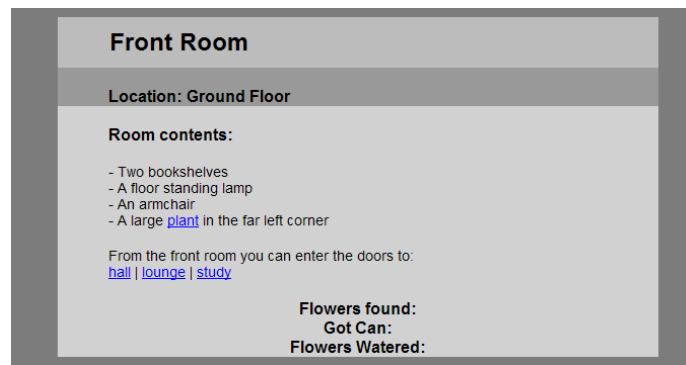


Figure 25. Example of a room in the linear condition of the House metaphor website

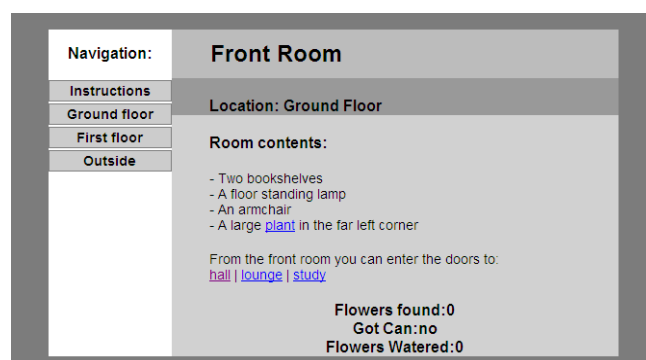


Figure 26. Example of a room in the hybrid condition of the House metaphor website

Procedure

Participants completed the ECSA WA (Peterson et al., 2003) and the Cooper and Shepard (1973) test following on-screen instructions. They were given instructions relevant for their website navigation task (watering plants, job hunting, and finding witnesses), which they completed in their own time. Following the navigation task all participants were directed to create a sitemap representing the structure of the website using the Microsoft PowerPoint© slide. The NASA-TLX scale was filled in at the end of the session. Participants were reminded that the measure referred only to the navigation task, and not the sitemap construction.

Data Analyses

Inspection of Kolmogorov-Smirnov statistics for the covariates revealed visuospatial ability scores were normally distributed. The distribution of frequency of use was also normal. Confidence scores were negatively skewed and had a kurtosis coefficient of 3.89. For the navigation indices, none of the dependent variables were normally distributed. Due to strong skewness, the data were transformed using a base 10 logarithm, producing more symmetrical distributions.

Further assumption testing was conducted, with no serious violations noted for linearity, univariate and multivariate outliers, homogeneity of variances and multicollinearity (see Appendix E). All statistical analyses are reported with alpha set at .05 unless otherwise stated. All scale measures were treated as interval data.

Results

The mean ECSA WA score was 1.10 ($SD = .15$), and the mean score for the mental rotation task was 79.71 ($SD = 27.15$). Participants spent a mean of 14.82 ($SD = 6.56$) hours using computers per week, and mean confidence score was 7.43 ($SD = 1.70$).

Time

Table 17 shows descriptive statistics for total time on task and time spent on each node.

Table 17.
Means and Standard Deviations for Total Time on Task and Time spent per Node (sec) in Linear and Hybrid Conditions.

		Linear ($n = 44$)		Hybrid ($n = 47$)		Overall ($n = 91$)	
		Mean	(SD)	Mean	(SD)	Mean	(SD)
Time on task	House	368.58	(245.23)	316.81	(171.36)	345.20	(213.27)
	Town	529.16	(596.60)	346.86	(179.80)	438.01	(442.75)
	Social	540.17	(244.07)	522.67	(240.22)	531.42	(238.11)
	Overall	474.60	(392.30)	397.23	(216.03)	437.19	(320.11)

Time per node	House	2.15	(1.00)	2.21	(0.75)	2.08	(0.88)
	Town	1.96	(1.36)	2.52	(0.65)	2.24	(1.09)
	Social	2.23	(0.60)	3.54	(1.72)	2.89	(1.43)
	Overall	2.12	(1.06)	2.77	(1.27)	2.43	(1.19)

House $n = 31$, Town $n = 30$, Social $n = 30$

3x2 ANCOVA for time on task while controlling for cognitive style, spatial ability, frequency of use and confidence revealed a significant main effect for metaphor, $F(2,81) = 5.19$, $p < .01$; partial $\eta^2 = .11$, but not for structure. Post hoc tests showed House was significantly faster than Social ($p < .01$), but no differences were found between the other two pairings. Confidence was the only covariate that had a significant effect ($p < .01$). No significant interaction between metaphor and layout, ($p = .94$).

For time spent per node, 3x2 ANCOVA revealed significant main effects for both metaphor, $F(2,81) = 3.15$, $p < .05$, partial $\eta^2 = .07$; and structure, $F(1,81) = 10.33$, $p < .01$, partial $\eta^2 = .11$. Post hoc tests showed participants spent less time per node in House than Social ($p < .05$), but no differences were found between the other two pairings; and Linear was significantly faster than Hybrid. No significant interaction effect was found. There were no significant effects of any of the covariates. Results are illustrated in Figure 27.

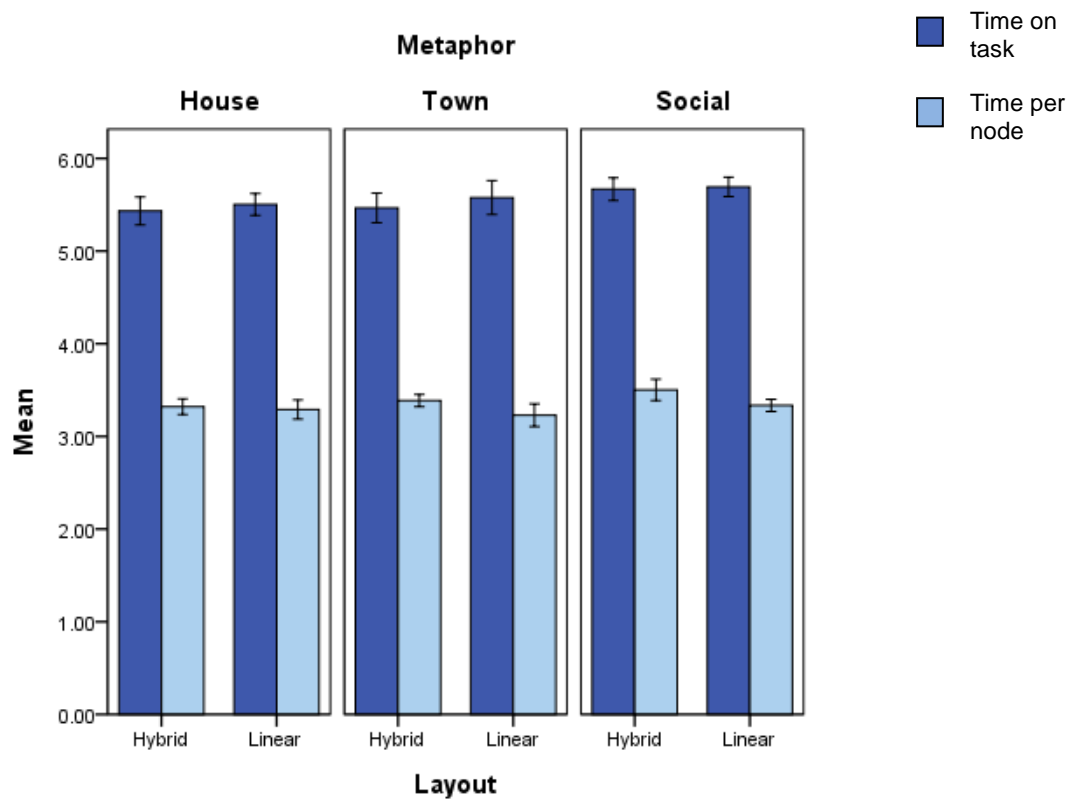


Figure 27. Effects of metaphor and hyperlink structure on time on task and average time spent per node.

Navigation Pattern

Table 18 shows descriptive statistics for the navigation indices (frequency of nodes and proportion of nodes revisited).

Table 18.

Means and Standard Deviations for Total Number of Nodes and Nodes Revisited in Linear and Hybrid Conditions.

		Linear		Hybrid		Overall	
		Mean	(SD)	Mean	(SD)	Mean	(SD)
Number of Nodes	House	245.18	(221.49)	178.43	(70.86)	215.03	(171.70)
	Town	269.93	(113.78)	172.00	(80.84)	220.97	(109.02)
	Social	275.80	(150.25)	197.67	(93.49)	236.73	(129.22)
	Overall	262.85	(167.52)	182.80	(81.33)	224.14	(138.28)
Nodes Revisited	House	84.74	(6.34)	83.18	(6.54)	84.04	(6.37)
	Town	88.92	(3.26)	81.92	(6.71)	85.44	(6.27)
	Social	88.06	(4.01)	82.97	(6.71)	85.51	(6.66)
	Overall	87.13	(5.05)	82.70	(6.93)	84.99	(6.40)

House $n = 31$, Town $n = 30$, Social $n = 30$

3x2 between-groups ANCOVA was performed measuring the effect of metaphor and structure on total number of nodes visited and proportion of nodes revisited while controlling for cognitive style, spatial ability, frequency of use and confidence. For number of nodes visited there was no significant interaction between metaphor and structure; no significant main effects were found; and there were no significant effects of the covariates. For proportion of nodes revisited, no significant main effects were found metaphor or structure; and there were no significant effects of the covariates. Detailed results can be found in Appendix E.

Sitemap

Descriptive statistics for correct connections made between nodes on the sitemap are shown in Table 19.

Table 19.
Means and Standard Deviations for Proportion of Correct Connections (%) in Sitemap for Linear and Hybrid Conditions.

		Linear		Hybrid		Overall	
		Mean	(SD)	Mean	(SD)	Mean	(SD)
Overall Connections	House	35.71	(13.77)	33.42	(13.41)	34.68	(13.43)
	Town	14.76	(12.51)	6.43	(4.09)	10.59	(10.08)
	Social	13.01	(9.22)	10.95	(6.94)	12.02	(8.09)
Landmark Connections	House	48.53	(20.67)	38.69	(23.25)	44.09	(22.07)
	Town	24.44	(17.67)	13.33	(8.21)	18.89	(14.67)
	Social	20.56	(12.94)	21.11	(11.73)	20.83	(12.14)

House $n = 31$, Town $n = 30$, Social $n = 30$

A paired-samples t-test revealed that the proportion of correct connections made from landmark nodes was significantly higher than the correct connections made from the other nodes $t(90) = -8.35, p < .001$.

2x3 ANCOVA revealed there was a significant main effect of metaphor on overall connections, $F(2,81) = 45.48, p < .001$, partial $\eta^2 = .53$, and on landmark connections, $F(2,81) = 18.80, p < .001$, partial $\eta^2 = .32$ (see Figure 28). For both dependent variables, post hoc analyses revealed a significant difference between House and Town ($p < .001$), and House and Social ($p < .001$), but not between Town and Social. Structure did not have a significant effect on neither overall or landmark connections. None of the covariates had a significant influence (see Appendix E for complete results).

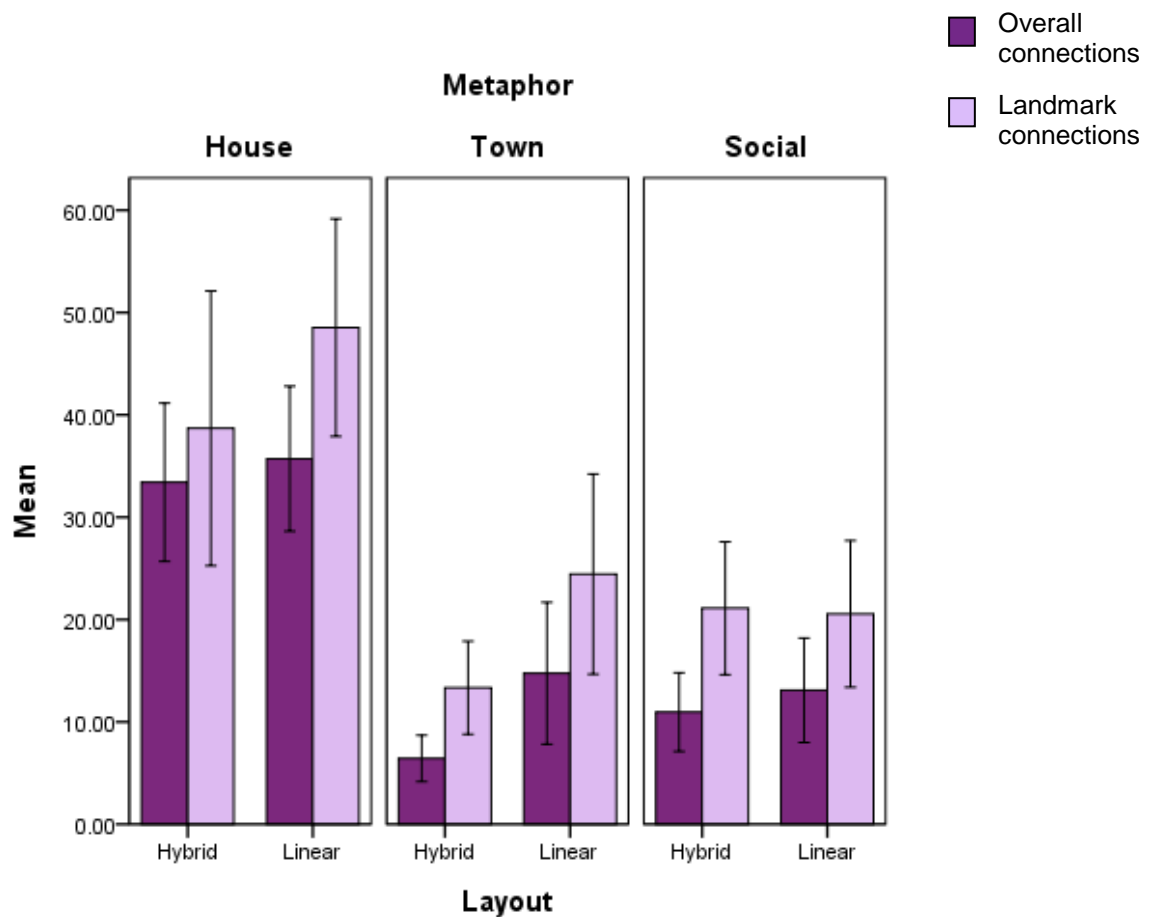


Figure 28. Percent of correct overall and landmark connections made in sitemaps for House, Town and Social metaphors.

Pearson's correlation analysis was carried out measuring the relationship between sitemap accuracy and the navigation measures, revealing no significant correlations. See Appendix E for full correlation matrix.

Cognitive Workload

Descriptive statistics for the total cognitive workload scores are presented in Table 20, workload scores for the individual dimensions can be found in Appendix E.

Table 20.

Means and Standard Deviations for NASA-TLX scores in Linear and Hybrid Conditions.

		Linear		Hybrid		Overall	
		Mean	(SD)	Mean	(SD)	Mean	(SD)
Total Workload	House	67.37	(10.81)	68.45	(10.52)	67.8565	(10.52)
	Town	64.54	(9.56)	60.99	(9.61)	62.7668	(9.59)
	Social	68.11	(15.19)	68.29	(10.26)	68.2000	(12.74)
	Overall	66.70	(11.87)	65.85	(10.50)	66.2918	(11.18)

A 3x2 ANCOVA was conducted measuring the effect of metaphor and structure for total perceived cognitive workload. No significant main effects were found. There were no significant effects of any of the covariates, and no significant interaction between metaphor and structure. 3x2 ANCOVAs were carried out measuring the effect of the independent variables on the six individual workload dimensions. For mental demand, no main effects and no interaction effect were found of metaphor and structure. Significant effects were found of the confidence and visuospatial ability covariates, $F(1,81) = 4.91, p < .05$, partial $\eta^2 = .06$ and $F(1,81) = 5.41, p < .05$, partial $\eta^2 = .06$ respectively. For physical demand, no main effects and no interaction effect were found of metaphor and structure. A significant effect of the visuospatial ability covariate was found, $F(1,81) = 10.30, p < .01$, partial $\eta^2 = .11$. For the effort dimension, significant main effects were found for both structure, $F(1,81) = 5.15, p < .05$, partial $\eta^2 =$

.06; and metaphor, $F(2,81) = 3.28$, $p < .05$, partial $\eta^2 = .08$. Post hoc tests showed there was a significant difference between House and Social ($p < .05$), but not between House and Town, and Town and Social. For the frustration dimension there was a main effect of structure $F(1,81) = 5.18$, $p < .05$, partial $\eta^2 = .06$, but no main effect of metaphor. Confidence was the only covariate with a significant effect on effort and frustration ($p < .05$). No significant effects of any of the variables were found on the performance and temporal demand dimensions. Full output can be found in Appendix E.

Discussion

Results revealed significant effects of metaphor and structure on the two time measures (time on task and time per node). Time on task was significantly affected by metaphor with participants taking less time to solve the task in the House condition. Structure did not affect total time on task. Both structure and metaphor had an effect on average time spent per node, with people spending less time per node in the House condition and in the linear condition. Of the four covariates (WA cognitive style, visuospatial ability, confidence, and frequency of use), only confidence had a significant influence on the results

(time on task). There were no significant findings related to navigation performance (nodes visited and nodes revisited), neither of the independent variables nor the covariates.

For of the mental representation measures (correct connection and correct landmark connections) there was a trend towards increased accuracy in the linear condition; however the results did not reach a significant level. A significant effect was found of metaphor on the mental representation measures. Again, the covariates were not found to have significant effects on the results. No significant relationships were found between overall correct connections in the sitemap and any of the navigation measures.

No significant effects were found of metaphor or structure total workload scores, however examining the six dimensions individually resulted in some significant findings, particularly as regards the individual differences covariates. Visuospatial ability had an effect on mental and physical demand, with higher scores on the visuospatial test being associated with lower perceived mental and physical demand. Confidence had an effect on mental demand, effort, and frustration; higher confidence scores were associated with lower perceived effort and frustration. Metaphor

had an effect on the effort and frustration dimension scores, with the House condition resulting in lower scores. Structure affected scores on the effort dimension, in that the hybrid condition resulted in significantly higher perceived effort than the linear condition.

The results for metaphor only partly support the hypotheses. The House metaphor resulted in participants solving the task quicker, but their navigation patterns did not differ between the conditions. The findings are not in agreement with the results of the previous study. In Study 4, results findings indicated significantly lower levels of disorientation (as measured by proportion of nodes revisited) in the House condition compared to the Town and Social conditions. Although the navigation behaviour did not differ, the results in terms of accuracy of mental representations suggest the House may perhaps be more easily retained and integrated as a concept. This is reflected in the participants reporting lower levels of effort and frustration in the House condition.

In terms of hyperlink structure the results were only partly in line with predictions. The finding that participants spent less time on average per node in the linear condition is interesting in

that it could suggest a slightly different approach to the contents; however, it is also likely that it was simply the limited navigational options that resulted in less deliberation being required when considering path choice. Although the effect of hyperlink structure on mental representation did not reach significance, the data still suggested it might be easier to form an accurate mental representation after interacting with the linear structure. This can possibly be seen as a consequence of participants having to spend less time processing navigational choices, thus freeing up resources to process the contents. Alternatively, it could be a result of 'forcing' participants to approach the environment in a systematic fashion. There were no significant differences between the linear and hybrid conditions in terms of navigation indices and inferred disorientation, although the data did show participants tended to visit more nodes in the linear condition. The linear condition gave users little navigational freedom and any revisiting of nodes required tracking back across all the intermediate nodes, so on this basis it can be argued that comparing the two conditions in terms of path length, and to a certain extent time, cannot offer any meaningful findings. Nevertheless, a key part of the rationale for the present

study was the prediction that cognitive style would have an effect on the results in relation to hyperlink structure. Following previous research (e.g. Calcaterra et al., 2005; Dufresne & Turcotte, 1997; Lee et al., 2005; Liegle & Janicki, 2006; Reed et al., 2000), this should have been particularly evident in the linear condition, in that the strict structure should have 'boosted' the performance of individuals with a wholist bias relative to those with an analytic bias. This did not occur. Two explanations seem to present themselves; one is that because of the frequent exposure to hypertext systems people, regardless of cognitive processing style, have formed mental models of the typical hypertext structure. The other is that the linear structure, which can be viewed as somewhat simplified, may have had beneficial effects on analytics' performance as well, and thus results show no effect of cognitive style on navigation performance and accuracy of mental representations.

The findings of the previous study showed a significant positive relationship between improved navigation performance and improved accuracy. This was not found in the present study, which showed no significant relationship between scores on the sitemap task and the four navigation measures. However, the

significant relationship found in Study 4 did only occur in the retrieval phase of the task. The present study measures overall performance, in other words both search and retrieval; it is therefore likely that the data from the search phase may have weakened the correlation.

The comparison between linear and hybrid hyperlink structures did not offer support to earlier findings. An issue that seems to be increasing in importance is that of the role of previous experience. A picture is starting to emerge in which prior experience and familiarity with the hypertext format has resulted in a situation where the typical quantitative navigation measures may not be sensitive enough to pick up any subtle differences in user's ability to find their way around a hypertext system. This is perhaps indicated by the fact that scores on the various cognitive workload dimensions that seem to suggest individual differences have an effect subjectively perceived performance, something that is not reflected in the performance outcomes. Addressing this issue, the next study will include a subjective measure of disorientation.

5.4. Study 6: Self-Report Measure of Navigation Performance

This study included a self-report measure of disorientation in order to examine whether there was a relationship between individuals' perception of the navigation experience and the navigation indices introduced in the previous studies. The relevance of subjective and objective measures of navigation performance is discussed.

The results of the two previous studies indicated that the measures of navigation behaviour and performance may not be reliable reflections of how easy a hypertext structure is to use, and may not give accurate indications of issues such as disorientation. One of the key reasons for this may be that hypertext systems have become commonplace, and that users especially within the population the current research draws its samples from, have formed solid internal representations as a results of frequent exposure. The results of Studies 4 and 5 indicated that a direct relationship is not present between performance and accuracy on mental representations of an environment, or between performance and subjective evaluations of task difficulty and cognitive workload. It has been argued that apart from efficiency alone (e.g. time on task and path length), one of the main reasons for wanting to keep levels of

disorientation among users at a minimum is to facilitate the formation of mental representations of hypertext environments (e.g. Amadiou et al., 2009). This calls into question the usefulness of assessing a hypertext system's ease of navigation based primarily on assessing structural disorientation.

Ahuja and Webster (2001) argued that measuring disorientation by means of examining actions (e.g. nodes visited and revisited) could be problematic in that using indirect measures and operationalising disorientation in terms of degradation in navigation performance may not be an accurate expression of a task situation. For example, a user who explores a website, and thus visits and re-visits a high number of nodes may be classed as disoriented despite not actually experiencing disorientation. In other words, more emphasis needs to be put on measuring conceptual disorientation. In Woods' (1984) framework, disorientation occurs when "the user does not have a clear conception of relationships within the system, does not know his present location in the system relative to the display structure, and finds it difficult to decide where to look next within the system" (pp. 229-230). While an inability to conceptualise the relationship between the different nodes within

a hypertext system could potentially be measured through looping behaviour and slow task times, a more direct expression is map drawing. However, map drawing alone does not give any indications about how users experience the navigation situation. Therefore, it would still need to be supplemented by a disorientation measure.

The present study includes a subjective measure of disorientation; a questionnaire developed by Ahuja and Webster (2001). The aim of this study is to examine whether this measure is sensitive enough to register what may be subtle differences in participants' evaluations, and whether subjective evaluation is related to objective performance and behaviour measures. Furthermore, while the previous studies in this chapter have shown a consistent effect of metaphor on sitemaps, the effect on the various navigation indices has been inconsistent and do not offer a basis for firm conclusions. If metaphor has an effect on the subjective disorientation measure, this may help clarify whether metaphor does affect levels of disorientation.

It is predicted that there will be a significant positive relationship between perceived disorientation and the navigation measure that is indicative of looping behaviour, proportion of

nodes revisited. It is also predicted that there will be a significant positive relationship between perceived disorientation and number of correct connection made in the sitemap task. For metaphor, it is predicted that perceived disorientation will be significantly lower in the House condition than in the Town and Social conditions.

Method

Participants

120 individuals took part in the study: 17 male and 103 female. Age ranged from 19 to 38 with a mean of 19.95 years ($SD = 2.25$). Participants were psychology undergraduate students at the University of Leicester receiving course credits for their participation.

Design

A between-groups design was used, measuring the effect of metaphor (3 levels: House, Town, and Social) on navigation performance (time on task, time per node, number of nodes and proportion of nodes revisited); cognitive workload, as measured by the NASA-TLX (Hart & Staveland, 1988); and disorientation as measured by scores on the Web Disorientation Questionnaire (Ahuja & Webster, 2001). WA cognitive style and spatial ability

were kept as covariates, measured by the ECSA WA (Peterson et al., 2003), and Cooper and Shepards Mental Rotation Test (1973) respectively.

Materials

Materials consisted of the ECSA WA (Peterson et al., 2003), and Cooper and Shepards Mental Rotation Test (1973). The same website was used as in Study 7, comprising a House, Town and Social version. The same Microsoft PowerPoint© slides were used for the sitemap task as in previous studies (see p. 168).

An adapted version of Ahuja and Webster's WDQ (2001) was used to measure perceived disorientation (see Table 21). This scale was reported to have high internal consistency (Cronbach's $\alpha = .90$) (Amadiou et al., 2009). The questionnaire consists of 11 statements about the navigation experience, and responses are recorded on 7-point Likert-type scales (1 = strongly disagree, 7 = strongly agree)

Table 21.
Disorientation Questionnaire Items.

1.	I felt lost
2.	I was confident I was heading in the right direction
3.	It was difficult to find a page that I had previously viewed
4.	Navigating between pages was a problem
5.	I always knew my current position in the website
6.	Finding a page I had been to previously was not a problem
7.	After browsing for a while I had no idea where to go next
8.	I felt disoriented
9.	I felt like I was going around in circles
10.	I didn't know how to get to my desired location
11.	I had no problem going back and forth between the pages

Procedure

Participants completed the ECSA WA (Peterson et al., 2003) and the Cooper and Shepard (1973) test following on-screen instructions. They were randomly assigned to a metaphor and given related instructions for the navigation task (see Table 11). After completing the navigation task all participants were directed to create a sitemap representing the structure of the website using the Microsoft PowerPoint© slide. Participants then completed the Web Disorientation Questionnaire (WDQ). The NASA-TLX scale was filled in at the end of the session. Participants were informed that the measure referred only to the navigation task, and not the sitemap construction.

Data Analyses

Of the four covariates, only visuospatial ability scores were normally distributed. WA cognitive style, frequency of use and

confidence showed similar patterns as in previous studies (see Appendix F for details).

The WDQ was scored from 1 (high disorientation) to 7 (no disorientation), and negatively worded items were reverse coded. Possible scores ranged from a minimum of 11 to a maximum of 77.

The navigation variables (time on task, time per node, number of nodes, and nodes revisited) were transformed using Log10 in order to obtain normal distributions. Further preliminary assumption testing was conducted, with no serious violations noted for linearity, univariate and multivariate outliers, homogeneity of variances and multicollinearity (see Appendix F). All statistical analyses with alpha set at .05.

Results

The mean ECSA WA score was 1.11 ($SD = .13$), and the mean score for the mental rotation task was 91.43 ($SD = 29.63$). The mean score for the Web Disorientation Questionnaire was 58.15 ($SD = 7.28$). Mean hours of computer use per week was 15.78 ($SD = 3.56$), and mean confidence score was 7.33 ($SD = 1.12$).

Time

Table 22 shows descriptive statistics for time on task and time spent on each node.

Table 22.

Mean and Standard Deviations for Total Time on Task and Time Spent per Node (sec) in Each Metaphor Condition.

	House (<i>n</i> = 40)		Town (<i>n</i> = 39)		Social (<i>n</i> = 40)		Overall (<i>n</i> = 119)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Time on task	228.08	(102.20)	359.47	(153.56)	490.74	(322.05)	359.43	(238.78)
Time per node	2.24	(1.10)	2.46	(1.05)	2.93	(1.49)	2.54	(1.25)

1x3 ANCOVA showed there was a significant influence of metaphor on time on task, $F(2,113) = 23.31$, $p < .001$, partial $\eta^2 = .29$. Post hoc tests (Bonferroni) showed there was a significant difference between all three conditions for time on task, House was faster than Town ($p < .001$) and Social ($p < .001$), and Town was faster than Social ($p < .05$). The confidence and visuospatial covariates had influence on the results, $F(2,113) = 4.47$, $p < .05$, partial $\eta^2 = .04$ and $F(2,113) = 4.41$, $p < .05$, partial $\eta^2 = .04$ respectively.

No effect was found for metaphor or any of the covariates on time spent per node ($p = .07$). Full output can be found in Appendix F.

Navigation Pattern

Table 23 shows descriptive statistics for frequency of nodes and proportion of nodes revisited.

Table 23.

Mean and Standard Deviations for Frequency of Nodes and Proportion of Nodes Revisited in Each Metaphor Condition.

	House (<i>n</i> = 40)		Town (<i>n</i> = 40)		Social (<i>n</i> = 40)		Overall (<i>n</i> = 120)	
	Mean	(<i>SD</i>)	Mean	(<i>SD</i>)	Mean	(<i>SD</i>)	Mean	(<i>SD</i>)
Frequency	112.15	(47.58)	164.97	(73.17)	183.12	(110.01)	153.42	(85.89)
Proportion Revisited	72.97	(9.19)	80.11	(8.34)	80.43	(8.89)	77.83	(9.40)

1x3 ANCOVA showed there was a significant effect of metaphor on frequency of nodes, $F(2,113) = 11.68$, $p < .001$, partial $\eta^2 = .17$. A post hoc test revealed significantly fewer nodes were visited in House than Town and Social ($p < .001$) and no significant difference between Town and Social. There were no effects of any of the covariates, although visuospatial ability was approaching a significant level ($p = .06$).

For on proportion of nodes revisited, 1x3 ANCOVA showed a significant effect of metaphor, $F(2,113) = 10.25$, $p < .001$, partial $\eta^2 = .15$. Post hoc tests (Bonferroni) showed that for both dependent variables, there was a significant difference between House and Town ($p < .01$), and House and Social ($p < .001$), but

not between Town and Social. None of the covariates had a significant effect.

Sitemaps

Table 24 shows the descriptive statistics for the proportion of correct connections made in the sitemaps. A paired-samples t-test showed there was a significant difference between accuracy for overall and landmark nodes, $t(117) = -10.73$.

Table 24.

Mean and Standard Deviations for Proportion of Overall Correct Connections and Correct Connections (%) to Landmark Nodes.

	House (<i>n</i> = 38)		Town (<i>n</i> = 40)		Social (<i>n</i> = 40)		Overall (<i>n</i> = 118)	
	Mean	(<i>SD</i>)	Mean	(<i>SD</i>)	Mean	(<i>SD</i>)	Mean	(<i>SD</i>)
Overall connections	35.71	(15.04)	9.82	(5.87)	9.20	(5.60)	17.94	(15.64)
Landmark connections	47.59	(18.57)	15.00	(10.37)	16.46	(9.15)	25.99	(19.92)

1x3 ANCOVA showed there was a significant effect of metaphor on overall correct connections, $F(2,111) = 99.39$, $p < .001$, partial $\eta^2 = .64$; post hoc tests showed significantly more correct connections were made for House than for Town and Social($p < .001$). There was no significant difference between Town and Social. There were no significant effects of the covariates.

For landmark connections, $F(2,111) = 74.28$, $p < .001$, partial $\eta^2 = .57$. Posthoc tests showed significantly more correct

connections were made for House than for Town and Social ($p < .001$). There was no significant difference between Town and Social. There were no significant effects of the covariates. Detailed output can be found in Appendix F.

Cognitive Workload

Mean total cognitive workload score for House was 70.09 ($SD = 13.06$), for Town 69.79 ($SD = 13.85$), and for Social 72.75 ($SD = 14.09$). Descriptive data for the individual dimensions can be found in Appendix F.

1x3 ANCOVA showed there was no influence of metaphor or any of the covariates on total perceived workload. 1x3 ANCOVAs was carried out measuring the effect on the six individual workload dimensions, and results revealed effects of metaphor on Temporal Demand, $F(2,113) = 4.97$, $p < .01$, partial $\eta^2 = .07$; on Performance, $F(2,113) = 4.11$, $p < .05$, partial $\eta^2 = .05$; and on Effort, $F(2,113) = 3.09$, $p < .05$, partial $\eta^2 = .03$. Post hoc tests revealed that in general, the House condition gave lower scores than the Town and Social conditions (see Appendix F for detailed results) for Temporal Demand and Effort, and higher scores on Performance. None of the covariates had a

significant effect on any of the dimensions. Details can be found in Appendix F.

Self-reported Disorientation

Pearson's correlation analyses were carried out investigating the relationships between self-reported feelings of disorientation, and the navigation time and pattern dependent variables (for results, see Table 25). Because the distribution of total WDQ scores was positively skewed, the variable was transformed (log10) before carrying out the analyses.

Table 25.
Relationships (Pearson's r) Between Scores on Web Disorientation Questionnaire and Navigation Time and Pattern Measures.

	WDQ Score	Time on task	Time per Node	Frequency of Nodes	Proportion Revisited
WDQ Score	-	.30**	-.05	.38**	.32**
Time on task		-	.56**	.59**	.50**
Time per Node			-	-.34**	-.40**
Frequency of Nodes				-	.95**
Proportion Revisited					-

** $p < .01$

Pearson's correlation analyses were conducted measuring the relationship between WDQ scores and visuospatial ability, $r = -.14$. $p > .05$, and WDQ scores and WA cognitive style, $r = .15$. $p > .05$.

Predicting Perceived Disorientation from Navigation Performance

A hierarchical linear multiple regression analysis was carried out examining whether navigation pattern and time measures could predict WDQ scores. Navigation indices (number of nodes and proportion revisited) were entered in the first block, and time measures (time on task and time per node) were entered in the second block. The overall regression model was significant, $F(1,112) = 6.19, p < .001$, explaining 16.1% of the variance in WDQ scores. The second block (time measures) only explained 2.0% of the total variance. The coefficients indicated number of nodes was the only predictor variable contributing significantly to the model. The model is summarised in Table 26. Complete summary of the regression model can be found in Appendix F.

Table 26.

Summary of Hierarchical Linear Multiple Regression Analysis for Predicting WDQ Scores (N = 116)

	<i>B</i>	<i>SE B</i>	β
Step 1			
Frequency of nodes visited	26.57	8.94	.78*
Proportion of nodes revisited	-56.56	34.74	-.43
Step 2			
Frequency of nodes visited	-41.60	.45.05	-1.22
Proportion of nodes revisited	-61.84	36.33	-.47
Time on task	70.58	46.11	2.34
Time per node	-68.36	46.06	-1.96

* $p < .01$

Perceived Disorientation, Metaphor and Sitemaps

Mean WDQ score for the House was 56.97 ($SD = 8.58$), for the Town 58.41 ($SD = 6.56$), and for Social 59.05 ($SD = 6.56$). A 3x1 between-groups ANCOVA was conducted measuring the effect of metaphor on WDQ scores. Results showed there was no significant effect of metaphor, $F(1,111) = 1.39$, $p = .25$.

Further correlation analyses were conducted exploring whether a relationship was present between WDQ scores and performance on the sitemap task. Correlation coefficients were $r = -.20$, $p < .05$ for overall connections, and $r = -.18$, $p > .05$ for landmark connections. There was also a significant relationship between total perceived workload and WDQ scores, $r = .27$, $p < .01$.

Further Analyses

In order to further analyse the effect of metaphor on self-reported disorientation, specifically to examine whether an interaction was present between objectively measured disorientation (revisitation) and metaphor on WDQ scores, participants were coded into two categories according to proportion of nodes revisited. The 'High disorientation' group consisted of individuals who revisited a proportion larger than one SD above the mean; the 'Low disorientation' group consisted

of individuals who revisited a proportion smaller than one *SD* below the mean. A 3x2 between-groups ANCOVA was conducted measuring the influence of metaphor (3 levels) and disorientation (2 levels: Low and High) controlling for the covariates (as before). Results showed no influence of metaphor, $F(2,37) = .51$, $p > .05$; partial $\eta^2 = .03$, and a significant effect of disorientation group, $F(1,37) = 6.97$, $p < .05$; partial $\eta^2 = .16$. No significant interaction was found ($p = .10$). None of the covariates influenced the results significantly. Results are illustrated in Figure 29. See Appendix F for descriptive data and detailed results.

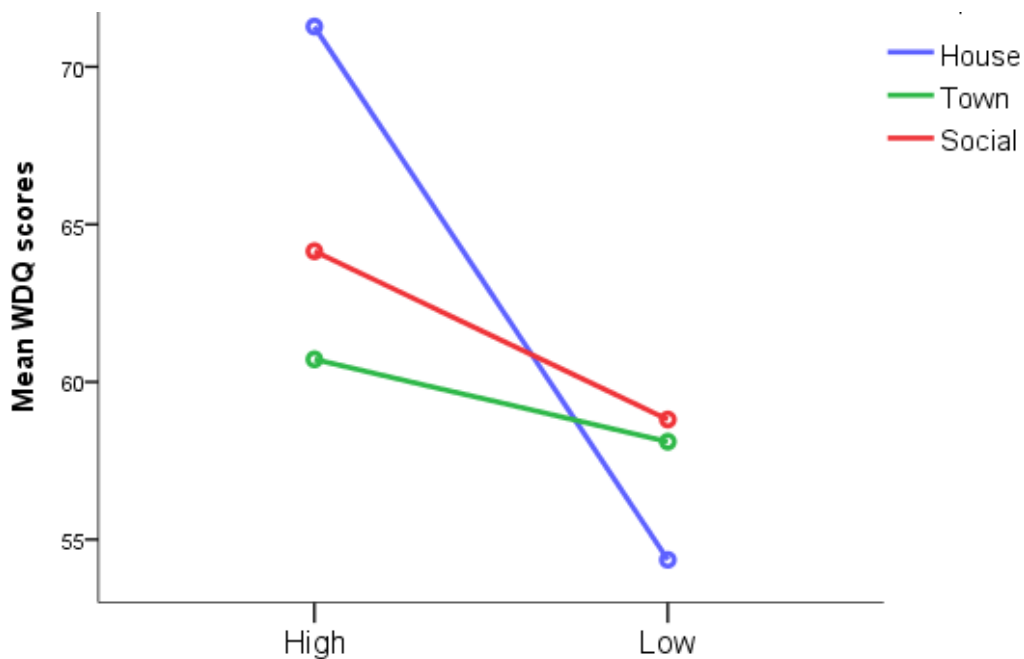


Figure 29. WDQ scores of High and Low Disorientation groups in the House, Town, and Social metaphor conditions.

Discussion

In line with predictions, the findings of the present study suggest an individual's perceived levels of disorientation are related to indirect, behavioural measures of disorientation, in this case revisiting nodes. As predicted, WDQ scores were found to be positively related to the navigation measure of disorientation, proportion of nodes revisited. WDQ scores were also significantly positively related to time on task and number of nodes visited, in that a lower feeling of disorientation was associated with faster response times and fewer of nodes visited. A multiple regression analysis indicated WDQ scores could be predicted by the navigation indices, in particular number of nodes visited. A higher number of nodes was predictive of higher levels of self-reported disorientation. For the sitemap task, a significant negative relationship was found between WDQ scores and overall number of correct connections. No significant relationship was found between WDQ scores and correct landmark connections. In other words, subjective disorientation was related to the overall quality of the mental representation of the hypertext system, but not to the effectiveness of landmark nodes. A significant positive correlation was found between

WDQ scores and total perceived workload, indicating that feeling disoriented was associated with a feeling of having to work harder to complete the task. According to predictions, self-reported disorientation would be lower in the House metaphor. Although the results showed a somewhat lower mean WDQ score in the House condition compared to the other two the effect did not reach a significant level. Furthermore, results indicated that WDQ scores were not influenced by participants' visuospatial ability or WA cognitive style.

For the time measures, results revealed a significant effect of metaphor on time on task, but not on average time spent per node. Visuospatial ability also influenced time on task, with higher scores being associated with taking less time. In general, participants took less time solving the task in the House condition than in the other two. They took the longest solving the task in the Social condition. A significant effect was also found of metaphor on number of nodes visited and number of nodes revisited. Again, performance was higher in the House condition, whereas there was no significant difference between the Town and Social conditions. None of the covariates had an effect on these variables. Metaphor had a significant effect on the mental

representation measures, with participants getting more connections correct in the House condition than in the other two conditions. No significant difference was found between Town and Social for correct connections. As in previous studies, more correct connections were made from the landmark nodes than from the other nodes in the sitemap. For perceived cognitive workload, no effect was found of metaphor on the overall scores; however the House condition elicited lower scores on the dimensions measuring temporal demand and effort. Furthermore, as measured by the performance dimension, participants were more satisfied with their own performance in the House condition than in the two other conditions.

Results also showed that perceived disorientation can be predicted by path length (number of nodes); the longer the path, the higher the disorientation levels. Also supporting the hypotheses, levels of perceived disorientation was related to sitemap accuracy; higher perceived disorientation was associated with fewer correct connections. Contrary to predictions, metaphor did not affect perceived disorientation. Although inspection of the data showed WDQ scores were lower in the House condition, this did not reach a significant level. When

considering the theories on conceptual and structural disorientation (Conklin, 1987; Cress & Knabel, 2003), this is an interesting finding. Whereas metaphor had an effect on disorientation in terms of navigation performance (proportion of nodes revisited), it did not affect users' subjective experience of disorientation. That is, there appeared to be some degree of dissociation between what participants thought and how they behaved. Although the interaction was not significant, the results did suggest a more congruent relationship between subjectively perceived disorientation and the objective disorientation measure within the House metaphor than the other two. In other words, in the Town and Social conditions there was more of a tendency for participants to report feeling the same level of disorientation regardless of their actual behaviour. A possible explanation for this finding could be that familiarity in terms of prototypicality somehow makes disorientation more apparent to an individual; in other words losing your way within a familiar, typical environment exaggerates the subjective feeling of disorientation. In a less familiar environment, the expectation of being able to find your way may be lower, thus leading to a higher threshold for feeling disoriented.

In the studies in this chapter, the findings concerning the effect of individual differences (visuospatial ability, WA cognitive style, confidence, and frequency of use) on navigation measures, disorientation, and accuracy of mental representations have so far been inconsistent. Rather than affecting navigation performance and sitemap accuracy, the measures have been found to have an effect on aspects of perceived workload. In general high visuospatial ability, analytic processing bias, high confidence, and high frequency of use have led to participants feeling less frustrated, and the tasks feeling less demanding and requiring of effort. Of the four measures that have been included in order to account for individual differences visuospatial ability has been closer to having an effect on the behavioural outcomes. In the present study, the variable was approaching a significant effect on frequency of nodes, a measure that has been found to be closely related to disorientation (as measured by looping behaviour and WDQ scores). Visuospatial ability will therefore be included in the next study in this chapter.

The findings as regards WA cognitive style have not been in line with predictions. The value of the measure in the present context is debatable. One reason for this may be that the majority

of previous studies that have demonstrated the relevance of cognitive style for hypertext navigation were based on the field dependence-independence style framework. Due to the conceptual overlap that has been demonstrated between cognitive style and visuospatial ability (see Section 4.2), and to an extent also the overlap between the cognitive style and prior knowledge, it can be argued that many previous studies (e.g. Dufresne & Turcotte, 1997; Lee et al., 2005; Palmquist & Kim, 2000; Reed et al., 2000) measured the relationships and effects of visuospatial ability and expertise, not cognitive style, on navigation. As such, the empirical basis for including cognitive style in the present research is somewhat diminished. The theoretical basis is still valid; differences in the way an individual organises and processes information are very likely to manifest in tasks such as navigation. On a fundamental level, the problem lies in what Rayner (2011) identified as a recurring theoretical tautology within the style literature. There is no single meta-theory of cognitive style, rather a number of theories, each with their individual models and measures. Each theory-model-measure cycle then becomes self-affirming, making difficult to consolidate findings across studies. For this reason, WA cognitive

style will not be included in the remaining studies, and the focus will instead be on visuospatial ability.

Chapter 6

6 Studies 7-8

6.1. Prototypical and Familiar Source Domains

This chapter investigates further the role of prior knowledge and familiarity in the effectiveness of interface metaphors. In particular the focus is on the difference between pre-existing knowledge about a prototypical environment compared to knowledge about an actual environment that does not adhere to a particular prototype.

The manipulations of the metaphors described and analysed in the previous chapter were based on familiarity and spatiality of the source domains. The House was based on a familiar and spatial domain; the Town was based on an unfamiliar and spatial domain; and the Social was based on an unfamiliar and non-spatial domain. Although the results were somewhat inconsistent, findings suggested that basing a metaphor on a familiar source domain, more so than spatial,

facilitated navigation performance and development of internal representations of the environment.

In evaluating the results, a question arose as to the nature of the concept of familiarity in this context. Prior knowledge and repeated exposure forms part of an individual's familiarity with an environment or domain, but prototypicality is also an important aspect of familiarity. As described in the previous chapter, research (e.g. Alba & Hasher, 1983; Arbuckle et al., 1994; Peron et al., 1990) has suggested people find it easier to remember and form mental representations of environments that conform to pre-existing schematic representations. The Town condition based on a fictitious place was included in the experimental design to allow conclusions to be drawn about the role of prior knowledge in metaphor. However, the comparison between the House and Town did not account for differences in type of familiarity. The differences between the House and Town conditions (which were both spatial) could lie in the House having more readily accessible prototypical features than the Town, but because the Town was unfamiliar it was not possible to comment on this. The differences could be based on the House condition adhering to conventions that apply to that particular

category of environments (e.g. Glucksberg & Keysar, 1993; Rosch et al., 1976). This question will be addressed in Study 7.

6.2. Study 7: Familiarity and Metaphor – Further Investigation

The present study focused mainly on the effect of familiarity of metaphors. The study was designed to examine the effect of two different aspects of familiarity in metaphor source domains; familiarity through prototypicality, and familiarity only through repeated exposure.

Kirasic (1991) examined the role of familiarity and age-related differences in learning environmental layouts. This particular study is of relevance to the present research due to consistent findings showing that visuospatial ability declines with age (e.g. Halpern & Collaer, 2005). Kirasic measured recognition and recall of the layout of two different supermarket environments: one familiar supermarket the participants had visited before and one novel, unfamiliar supermarket. This corresponds to what Arbuckle et al. (1994) referred to as schema on/off situations. Results showed that familiarity did not have an effect on recall accuracy. Kirasic suggested that although the familiar and novel supermarkets were different in terms of specific features of their layout, both of them adhered to a prototypical supermarket schema. The availability of this general schema could therefore have been the reason behind the lack of effect of familiarity on performance.

The situation described by Kirasic (1991) forms part of the rationale behind the House metaphor used in the studies reported in the previous chapter. Participants were able to draw on a general schema of a house layout. This type of schema was not available in the Town metaphor. Therefore, while the results obtained in studies 4 to 6 shed some light on the value of prior knowledge in navigating and forming mental representations of hypertext environments, they do not enable conclusions to be drawn about the value of schematic knowledge and prototypicality. In other words, what would the results have looked like if the Town was somewhere they had visited several times in the past? In order to answer this question, the present study includes a familiar but not prototypical environment. Because the sample for this study is drawn from undergraduate students at the University of Leicester, the environment that best fits these criteria is the university campus. The participants are exposed to this environment on a daily basis, yet it does not conform to the same strict conventions in terms of layout and structure as a house.

Based on theories of prototypicality, it is predicted that navigation performance will be higher in the House than the

Campus and Town conditions (i.e. shorter time on task, fewer nodes visited and lower proportion revisited). It is also predicted that the House conditions will result in increased sitemap accuracy (correct connections) and lower self-reported disorientation (WDQ scores) than the other two conditions.

Method

Participants

46 individuals took part in the study: 10 male and 36 female. Age ranged from 19 to 38 years with a mean of 20.43 ($SD = 3.48$). Participants were psychology undergraduate students at the University of Leicester receiving course credits for their participation. In order to ensure a certain level of familiarity with the campus environment all participants were recruited from the Year 2 cohort.

Design

A 1x3 between-groups design was used, measuring the effect of the independent variable metaphor (3 levels: House, Town, and Campus). Dependent variables were navigation performance (time on task, time per node, number of nodes, and proportion of nodes revisited); proportion of correct connections made on the sitemap; and self-reported disorientation, as

measured by the WDQ (Ahuja & Webster, 2001). Covariates were frequency of use, confidence, and visuospatial ability measured by Cooper and Shepard's Mental Rotation Test (1973).

Materials

Materials comprised the Cooper and Shepard's Mental Rotation Test (1973), the adapted version of Ahuja and Webster's Web Disorientation Questionnaire (2001) (see Table 21), confidence ratings (from 0 to 10) and frequency of use (hours per week). The same type of Microsoft PowerPoint© slides as in previous studies were used for the sitemap task, and the same websites were also used. However, the Social website was replaced with a website designed to represent the University of Leicester campus. Figure 30 shows an illustration of the website structure.

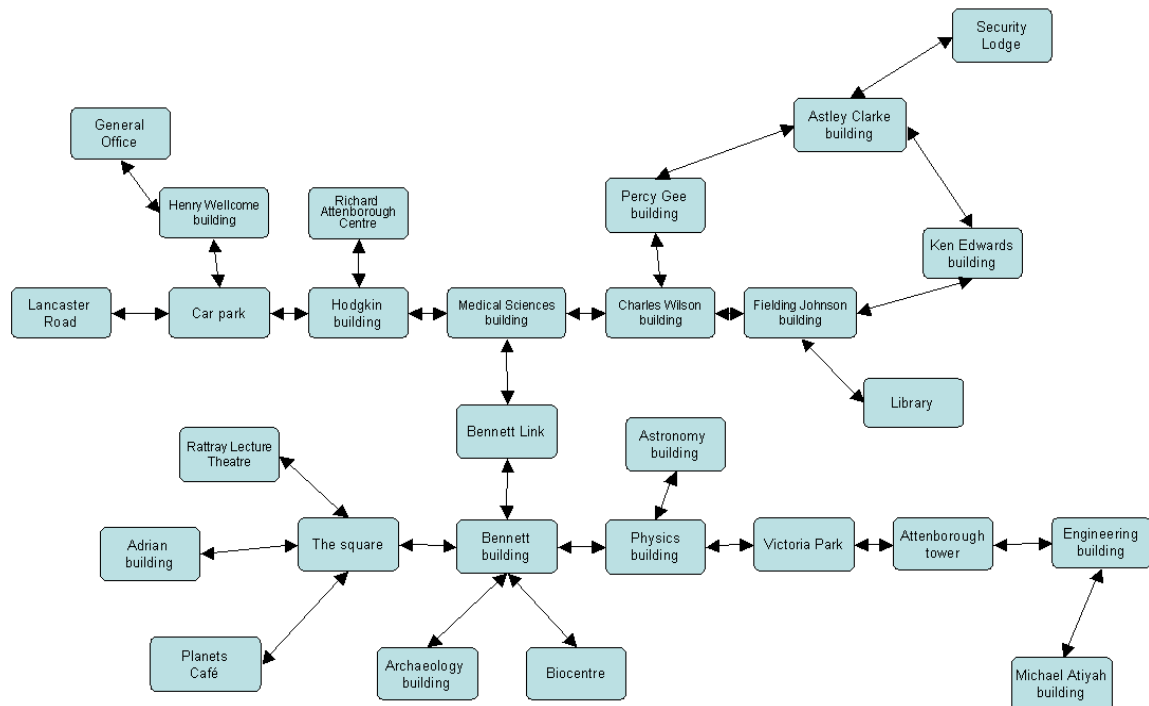


Figure 30. Structure of the website based on the University campus

The task in the Campus condition followed the same 5-step search and retrieval pattern as in previous studies. Figure 31 shows a description of the task as presented at the start of the website.

Campus Metaphor Version
You work for the University's Head of Security. Your task is to:
1) Pick up 5 documents from boxes in various buildings around campus
2) Go to the Security Lodge to get them stamped
3) Go to the VC's office in the Fielding Johnson building to get a signature
4) Return copies of the documents to the boxes in the 5 buildings
5) Take the originals back to the Security Lodge

Figure 31. Task instructions for Campus condition

Procedure

Participants completed the Cooper and Shepard (1973) test following on-screen instructions. They were randomly assigned to a metaphor and given related instructions for the navigation task. After completing the navigation task all participants were directed to create a sitemap representing the structure of the website using the Microsoft PowerPoint© slide. Participants then completed the WDQ. The NASA-TLX scale was filled in at the end of the session and informed that this measure referred only to the navigation task, and not the sitemap construction.

Data Analyses

Assumption testing was conducted, with no serious violations noted for linearity, univariate and multivariate outliers, homogeneity of variances and multicollinearity (see Appendix G). None of the navigation indices (time on task, time per node, frequency of nodes, and proportion of nodes revisited) were normally distributed. Due to strong skewness, the data were transformed using a base 10 logarithm, producing more symmetrical distributions. The WDQ data are treated as interval for the purpose of analyses, and all statistical analyses are with alpha set at .05.

Results

The mean score for the mental rotation task was 76.15 ($SD = 32.50$). The mean score for the WDQ was 54.50 ($SD = 5.79$). Mean hours of computer use per week was 16.07 ($SD = 7.14$), and mean confidence score was 7.65 ($SD = 1.53$).

Time

Table 27 shows descriptive statistics for time on task and time spent on each node.

Table 27.
Mean and Standard Deviations for Total Time on Task and Time Spent per Node (sec) in Each Metaphor Condition.

	House ($n = 14$)		Town ($n = 19$)		Campus ($n = 13$)		Overall ($n = 46$)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Time on task	407.88	(275.09)	361.64	(181.08)	319.17	(158.65)	363.32	(206.97)
Time per node	2.57	(.86)	1.86	(.98)	2.51	(1.21)	2.26	(1.05)

1x3 ANCOVAs were conducted measuring the effect on the two time variables individually. No significant effect was found of metaphor for time on task, $F(2,40) = .20$, $p > .05$; partial $\eta^2 = .01$. There was a significant effect of metaphor on time per node $F(2,40) = 3.34$, $p < .05$, partial $\eta^2 = .14$. Post hoc analyses revealed there were no significant differences between the

metaphor variables. No effect was found of any of the covariates for either time variable. Details can be found in Appendix G.

Navigation Pattern

Table 28 shows descriptive statistics for frequency of nodes and proportion of nodes revisited.

Table 28.

Mean and Standard Deviations for Frequency of Nodes and Proportion of Nodes Revisited in Each Metaphor Condition.

	House (<i>n</i> = 14)		Town (<i>n</i> = 19)		Campus (<i>n</i> = 13)		Overall (<i>n</i> = 46)	
	Mean	(<i>SD</i>)	Mean	(<i>SD</i>)	Mean	(<i>SD</i>)	Mean	(<i>SD</i>)
Frequency	153.43	(67.82)	211.63	(88.92)	144.00	(84.31)	174.80	(85.89)
Proportion Revisited	80.05	(7.10)	84.86	(5.75)	76.26	(11.57)	80.97	(8.75)

1x3 ANCOVAs were conducted measuring the effect on the two navigation pattern variables. A significant effect was found of metaphor for frequency of nodes $F(2,40) = 3.44, p < .05$, partial $\eta^2 = .15$. Post hoc analyses revealed there were no significant differences between the metaphor variables. None of the covariates had a significant effect. A significant effect was also found of metaphor for proportion of nodes revisited, $F(2,40) = 3.99, p < .05$; partial $\eta^2 = .17$. Post hoc analyses revealed there were no significant differences between House and Town or House and Campus, but there was a significant difference

between Town and Campus ($p < .05$). None of the covariates had a significant effect. Details can be found in Appendix G.

Sitemaps

Table 29 shows the descriptive statistics for the proportion of correct connections made in the sitemaps. A paired-samples t -test showed that accuracy for landmark nodes was significantly higher than for other nodes, $t(56) = 2.04$.

Table 29.

Mean and Standard Deviations for Proportion of Overall Correct Connections and Correct Connections (%) to Landmark Nodes.

	House ($n = 14$)		Town ($n = 19$)		Campus ($n = 13$)		Overall ($n = 46$)	
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Overall connections	40.41	(14.34)	12.59	(5.88)	21.61	(6.46)	24.87	(15.08)
Landmark connections	46.05	(21.94)	17.11	(7.59)	18.86	(9.95)	27.34	(19.59)

1x3 ANCOVA showed there was a significant effect of metaphor on overall correct connections, $F(2,40) = 24.42$, $p < .001$, partial $\eta^2 = .55$; Post hoc tests showed significantly more correct connections were made for House than for Town and Campus ($p < .001$), and for Campus than Town ($p < .05$). For landmark connections the ANCOVA result was $F(2,40) = 16.01$, $p < .001$, partial $\eta^2 = .45$. Post hoc tests showed significantly more correct connections were made for House than for Town and Campus (p

< .001). There was no significant difference between Town and Campus. There were no significant effects of the covariates. Details can be found in Appendix G.

Pearson's correlation analysis was carried out measuring the relationships between overall sitemap accuracy and the four different navigation measures (time and pattern). Results showed only one significant positive correlation, between overall sitemap connections and average time spent per node (see Appendix G for correlation matrix).

Self-reported Disorientation

Mean scores for the House, Campus and Town metaphor conditions were 54.29 ($SD = 4.83$), 51.61 ($SD = 2.57$), and 56.63 ($SD = 7.19$) respectively. Pearson's correlation analyses were carried out investigating the relationships between self-reported feelings of disorientation, and the navigation time and pattern dependent variables (for results, see Table 30). Because the distribution of total WDQ scores was positively skewed, the variable was transformed (\log_{10}) before carrying out the analyses.

Table 30
Relationships (Pearson's r) Between Scores on Web Disorientation Questionnaire and Navigation Time and Pattern Measures.

	WDQ Score	Time on task	Time per Node	Frequency of Nodes	Proportion Revisited
WDQ Score	-	.30**	-.31*	.63**	.55**
Time on task		-	.53**	.55**	.53**
Time per Node			-	-.42**	-.38**
Frequency of Nodes				-	.94**
Proportion Revisited					-

* $p < .05$; ** $p < .01$

A 3x1 between-groups ANCOVA was conducted measuring the effect of metaphor on perceived disorientation. After adjusting for the covariates, there was no significant effect of metaphors, $F(2,40) = 2.49$, $p > .05$; partial $\eta^2 = .11$. There was a significant effect of the covariate visuospatial ability on perceived disorientation, $F(1,40) = 4.19$, $p < .05$; partial $\eta^2 = .10$. Without adjusting for visuospatial ability, WDQ scores were significantly lower in the Campus condition than in the Town condition ($p < .05$), and there was no significant difference between Campus and House, and House and Town. For details, see Appendix G.

Discussion

Results revealed there was no significant effect of metaphor for time on task. A significant effect was, however, found on average time spent per node. Although post hoc tests showed the differences between the metaphor conditions did not

reach significance, there was a trend towards participants spending longer per node in the House and Campus conditions compared to the Town condition (and marginally longer in the House than the Campus condition). For navigation patterns, results showed there was a significant effect of metaphor for frequency of nodes. Participants visited fewer nodes in the Campus than the House and Town conditions; however according to post hoc tests, the differences did not reach a significant level. A significant effect was also found for proportion of nodes revisited. Participants revisited a smaller proportion of nodes in the Campus than the two other conditions, but post hoc tests showed the only significant difference was between Campus and Town. The covariates frequency of use, confidence and visuospatial ability did not affect the navigation time and pattern outcomes.

Results for self-reported disorientation showed there was no effect of metaphor on participants' scores after adjusting for the effect of visuospatial ability. Although not to a significant level, there was a trend towards lower disorientation scores in the Campus condition than the House, and lower in House than Town. Significant positive correlations were found between

WDQ scores and time on task, frequency of nodes, and proportion of nodes revisited. A negative correlation was found between WDQ scores and time spent per node, indicating that dwelling longer at each node was associated with lower perceived disorientation.

For sitemap accuracy, results showed a different pattern. A significant effect was found of metaphor for both overall correct connections and connections made from landmark nodes. Significantly more correct connections of both types were made in the House condition than Campus and Town, and more correct overall connections were made in Campus than Town (no difference for landmark connections between these two). No significant effects were found for any of the covariates.

Overall, results only partially supported the predictions. For both the subjective and objective disorientation measures, the results showed participants performed better in the Campus condition, and not in the House condition as hypothesised. For the sitemap task, the results were in line with the predictions, with the House condition resulting in more accurate representations of the hypertext systems. The dissociation that appears to be present between navigation and mental

representation performance is an interesting finding. In terms of navigation measures, the Campus metaphor gave faster times on task, fewer nodes overall and a smaller proportion of nodes revisited; in other words improved performance. Perceived disorientation did also seem to reflect navigation performance; higher perceived levels of disorientation was related to taking longer to solve the task, spending less time per node, visiting more nodes, and revisiting a higher proportion of nodes. However, the improved navigation performance and low levels of perceived disorientation found in the Campus condition were not reflected in the accuracy of the sitemaps, where the House condition generated significantly more accurate responses.

There was a significant relationship between visuospatial ability on perceived disorientation. More specifically, the influence of metaphor that was found of for WDQ scores diminished when visuospatial ability was taken into account. The results suggested visuospatial ability was of particular relevance in the Campus condition. This could be due to the Campus condition being based on a real environment which the participants had experience with traversing physically, and not a prototype that only exists in schematic form. It could of course be

argued that the House is a real environment too; however, the metaphor used in this study was based on a prototypical house, not an actual house the participants had been in. In the Campus condition, visuospatial ability is of relevance, as has been demonstrated in studies of real-world navigation (Hegarty & Waller, 2004; Hegarty & Waller, 2005). Therefore, individuals' ability to navigate the source domain may have affected their ability to navigate the hypertext target domain.

The findings of the present study show there is a differential effect of familiarity based on exposure and familiarity based on prototypicality. Exposure-based familiarity facilitates navigation performance, but does not necessarily produce more accurate mental representations of an environment. It is quite possible that this discrepancy is a result of inaccurate mapping between the participants' representation of the source domain (Campus) and the designer's representation of the same domain. Source-target mapping has been identified as a potential problem in terms of metaphor efficiency and usefulness (e.g. Nardi & Zarmar, 1993). A metaphor based on a prototype will arguably contain more general, flexible features that give users some 'leeway' when integrating the environment with their pre-

existing schematic representations. Metaphors based on existing environments will be less flexible, more dependent on individuals' interaction with the source domain, and more vulnerable to 'violations'; that is, if features or pieces of information do not match a user's schema it may cause conflict and be difficult to integrate and assimilate. For example, the saliency and importance of areas of campus may vary between individuals based on a number of different factors, such as how frequently they visit them and the importance of the activities they carry out there. This is supported by evidence of systematic distortions in cognitive maps, where individuals' judgement of spatial distance has been shown to be influenced by conceptual hierarchies (e.g. Stevens & Coupe, 1978).

6.3. Study 8: Comparison of Familiarity through Exposure via Navigation and Studying Maps

The main purpose of this study is to examine the robustness of findings in terms of metaphor and accuracy of internal representations. The study examines the effect of type of exposure on accuracy of internal representations by comparing sitemaps produced by participants who have performed a navigation task to that of participants who have merely studied a sitemap.

One of the most consistent findings within the literature on real-world navigation is that active exploration leads to greater knowledge of an environment than passive observation, for example via being guided or studying maps (e.g. Gibson & Crooks, 1982). According to Thorndyke and Hayes-Roth (1982) there are important differences in the type of knowledge people acquire from studying maps of an environment and from navigating an environment. Maps enable encoding of global spatial relationships, resulting in the development of survey knowledge; whereas navigation results in the development of route knowledge based on procedural knowledge. Thorndyke and Hayes-Roth based their proposition on experiments carried out in physical environments. Ishikawa, Fujiwara, Imai, and Okabe (2008) compared accuracy of mental representations (map drawing) of a physical environment between groups learning the

environmental layout through a paper map, Global Positioning Systems and direct experience and found that with direct experience, the task was rated as easier, and map drawings were significantly more accurate.

In the electronic domain, active navigation or exploration has been defined as involving an individual's interaction with an interface (e.g. mouse, keyboard, joystick) (Wilson, Foreman, Gillett, & Stanton, 1997). Wallet, Sauzéon, Rodrigues, and N'Kaoua (2008) compared the effect of active and passive exploration on the development of route knowledge (measures included map drawing and wayfinding) in a 3D virtual representation of an actual environment. The active approach involved manoeuvring around the environment using a joystick, whereas the passive involved visualising the environment without interacting. Results showed that active exploration lead to improved ability to navigate the real-world environment, and also more accurate map drawing (correctly connected route segments).

If transferred directly to hypertext systems, the findings would indicate that learning the configuration of the system through navigating, in other words following the hyperlinks,

would lead to more accurate mental representations than studying graphical representations of the system. However, due to the differences between physical and electronic environments, and 3D and 2D electronic environments, in terms of both perceptual cues available and type of interaction, this may not necessarily be the case. Nonetheless, website overviews in the shape of topological representations of the contents are a common navigational aid employed in web design and development. It is therefore relevant to examine whether active and passive exploration have differential effects on learning the layout of hypertext systems. In the context of the present research, it is also of interest to investigate whether a potential effect of exploration method is affected by metaphor. It is predicted that there will be an effect of exploration method, in that active exploration (navigation) of will result in higher sitemap accuracy than passive exploration (studying a map). Furthermore, based on findings from the previous study, it is predicted that sitemap accuracy will be significantly higher in the House than in the Campus and Town conditions.

Method

Participants

94 individuals took part in the study; 50 male 44 female. Age ranged from 19 to 38, mean age 20.20 ($SD = 2.92$). Participants were psychology undergraduate students at the University of Leicester receiving course credits for their participation.

Design

A 3x2x2 mixed design was used to compare the effect of training by exposure to maps and training by interacting through navigation. There were two between groups factors: metaphor (three levels: House, Town, and Campus) and exploration method (two levels: map or navigation). The within-groups factor was training (two levels: pre- and post-training). Post-training in the map condition was defined as having completed a three minute period of studying a sitemap, and in the navigation condition, training consisted of three minutes familiarisation with the website through browsing. The dependent variable (accuracy of internal representation) was measured by the ability to reproduce the map subsequent to training using a sitemap as in the previous studies. Visuospatial ability was entered as a

covariate, measured by Cooper and Shepard's Mental Rotation Test (1973).

Materials

Materials for the navigation condition comprised the same website and mental rotation test as used in the previous study. For training purposes in the map condition, a Microsoft PowerPoint© slideshow was designed with one slide containing task instructions, a second slide containing the sitemap, and a third slide signalling the end of the task. Figure 32 shows the task instructions for one of the variations of the map condition.

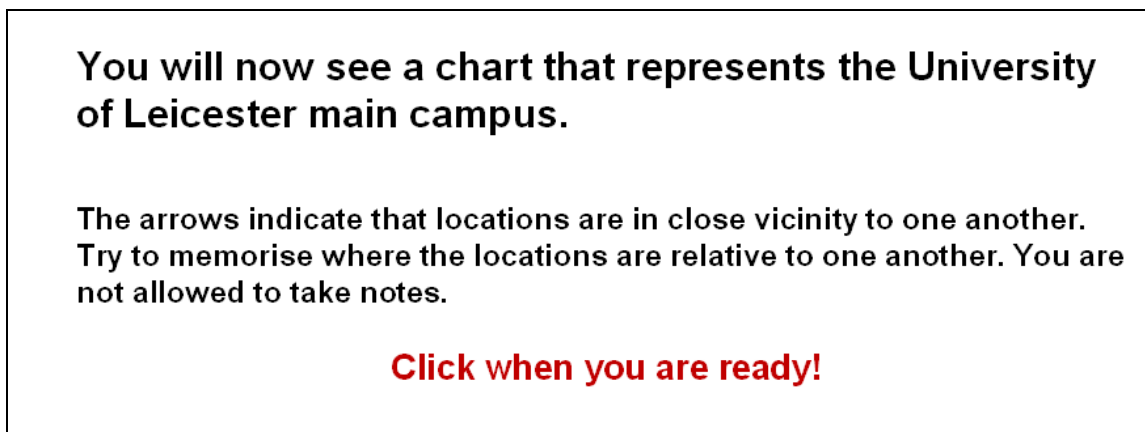


Figure 32. Instructions for the Campus in the map condition.

Procedure

In both the navigation and the map condition, participants were presented with a PowerPoint© map slide identical to the ones used in previous studies (see Figure 21), where the task was

to position boxes representing each node of the map in the correct position relative to one another. They first carried out this task without training/exposure, establishing a baseline for the accuracy measure. After completing this, participants spent three minutes exploring (navigation or map). After completing the exploration task, participants produced another sitemap, using the same material as previously.

In the map condition, participants were presented with the PowerPoint© starting slide containing the task instructions (see Figure 32). Participants started the slide show in their own time. Once the participants had clicked to start, they were presented with a map of the House, Town or Campus and were given three minutes to study this (see Figures on p. 161). After completing the exploration task, participants produced another sitemap, using the same material as previously. The procedure is illustrated in Figure 33.

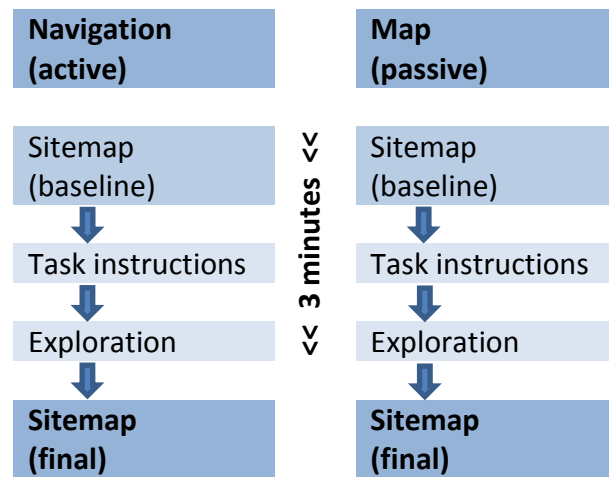


Figure 33. Structure of the Study 8 procedure.

Data Analyses

Preliminary assumption testing was conducted, with no violations noted for linearity, univariate and multivariate outliers, homogeneity of variances and multicollinearity (see Appendix H). Pre- and post-training scores were transformed using (log10) in order to obtain a normal distribution. All statistical analyses are reported with alpha set at .05.

Results

The mean score for visuospatial ability for the whole sample was 79.59 ($SD = 31.61$). Overall, pre-training accuracy was 15.82 ($SD = 11.15$) for the navigation condition, and 10.54 ($SD = 7.80$) for the map condition. Post-training accuracy was 44.53 ($SD = 22.71$) for the navigation condition, and 19.454 ($SD = 12.82$) for the map condition. Descriptive statistics for accuracy of sitemaps for the three metaphor conditions are presented in Table 31.

Table 31. *Mean and Standard Deviation for Correct Sitemap Connections Made in Map and Navigation Conditions Before and After Training*

		House (<i>n</i> = 32)		Campus (<i>n</i> = 34)		Town (<i>n</i> = 28)	
	Accuracy	Mean	(SD)	Mean	(SD)	Mean	(SD)
Map	Pre-training	16.75	10.54	6.30	3.15	8.78	4.10
	Post-training	23.00	17.55	17.95	9.18	17.78	10.73
Navigation	Pre-training	26.39	8.93	4.76	3.21	14.29	6.25
	Post-training	62.30	18.05	27.14	19.60	40.85	15.04

A 3x2x2 mixed ANCOVA was performed measuring the effect of metaphor, training, and exploration method on accuracy. Between subject variables were metaphor (House, Campus, Town) and training format (Map, Navigation), and within-subjects variable was training (pre- and post-training). Results are Greenhouse-Geisser adjusted due to violation of the assumption of sphericity. A significant main effect was found of training, $F(1,82) = 40.32$, $p < .001$; partial $\eta^2 = .33$. Significant main effects were also found for metaphor, $F(2,82) = 23.25$, $p < .001$; partial $\eta^2 = .36$; and for exploration method, $F(1,82) = 27.42$, $p < .001$; partial $\eta^2 = .25$. Post hoc tests (Bonferroni) revealed significant differences between the two exploration methods ($p < .001$), between pre-and post-training ($p < .001$), and between the three metaphors: House and Campus ($p < .001$), House and Town ($p < .001$), and Campus and Town ($p < .05$).

A significant interaction was found between and metaphor and exploration method $F(2,82) = 5.70, p < .01$; partial $\eta^2 = .12$. The covariate visuospatial ability did not have a significant effect on map accuracy, $F(1,82) = 3.10, p = .82$; partial $\eta^2 = .04$. Pre- and post-training scores by training format are illustrated in Figures 34 and 35. For full details, see Appendix H.

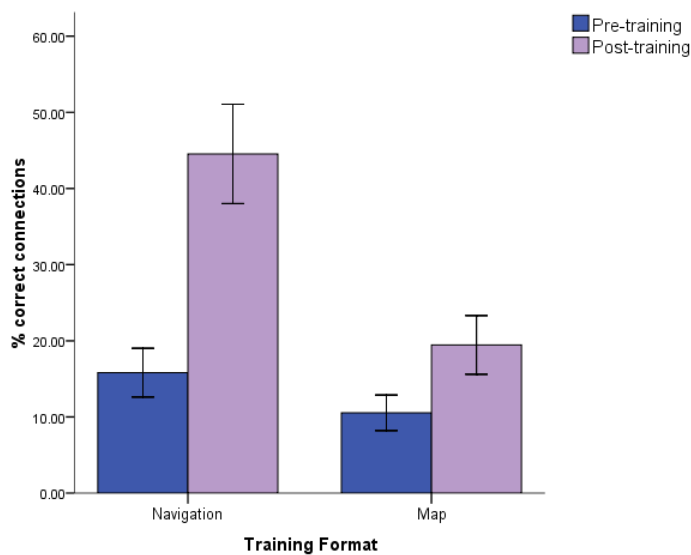


Figure 34. Mental Map Accuracy Scores Pre- and Post- Training for the Map and Navigation Training Formats (error bars represent 95% confidence interval).

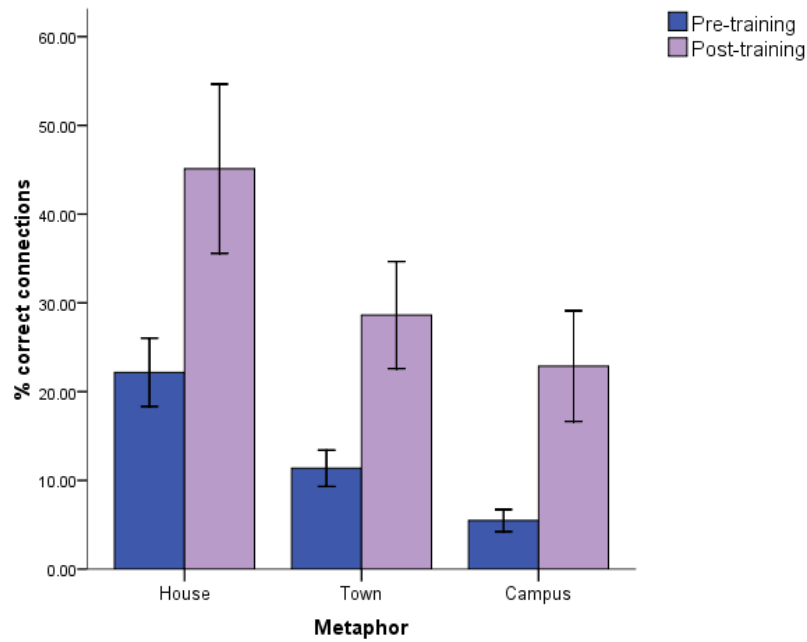


Figure 35. Mental Map Accuracy Scores Pre- and Post-Training in House, Campus and Town Metaphors (error bars represent 95% confidence interval)

In order to examine the effect of controlling for visuospatial ability further, the data was split according to exploration method. 1x3 between-groups ANCOVAs were then conducted measuring the effect of metaphor on post-training sitemap accuracy whilst controlling for visuospatial ability. In the active exploration group, results showed there was a significant effect of metaphor on sitemap accuracy $F(2,45) = 17.35, p < .001$; partial $\eta^2 = .44$, and a significant effect of the visuospatial ability covariate, $F(1,45) = 15.32, p < .001$; partial $\eta^2 = .25$. Post hoc test revealed there was a significant difference between House and Town ($p < .01$), House and Campus ($p < .001$), and Campus and Town ($p < .05$). In the passive exploration group

there was no significant effect of metaphor or of visuospatial ability. See Appendix H for full details.

Discussion

In line with predictions, results showed there was a significant effect of exploration method on sitemap accuracy. Specifically, active exploration through navigation lead to significantly more correct connections in the sitemaps compared to passive exploration though maps. A significant effect was also found for metaphor, with the House condition producing more accurate sitemaps than the Town condition, and the Town condition producing more accurate sitemaps than the Campus condition. Also, as expected, participants performed significantly better on the sitemap task after training than before training. A significant interaction was found between exploration format and metaphor. In the House and Town conditions active exploration gave significantly more accurate sitemaps than passive exploration; whereas in the Campus condition there was no significant difference between the two exploration methods. Visuospatial ability did not have a significant effect on sitemap accuracy overall. However when dividing the data according to exploration method, results showed that visuospatial ability had

a significant influence in the active exploration situation, but not in the passive.

The findings support the hypothesis that active exploration leads to more accurate internal representations of an environment compared to passive exploration. Thus, it seems that findings made in the study of physical environments (Ishikawa et al., 2008) and 3D virtual environments (Wallet et al., 2008) can be extended to apply to 2D environments, such as hypertext systems. However, the interaction effect found between exploration method and metaphor indicated that familiarity of the source domain a hypertext environment is built around is of importance in this context. As established in the previous study, navigation performance was not related to sitemap accuracy when the hypertext system was embedded in a metaphor based on an actual environment (Campus). Thus, the finding that active exploration did not lead to more accurate sitemaps than passive exploration in the Campus condition was to be expected. As previously discussed, this may be due to inconsistencies between individuals' internal representations of the Campus environment and the representation given by the designer. A prototypical environment like the House condition has more 'conceptual pegs'

(Paivio, 1971; Sadoski & Paivio, 2001) on which to base the sitemap, leading to increased accuracy. For the Town condition, it is likely that the lack of prior knowledge left more room for the different parts of the environment to be integrated into a schematic representation without the presence of previously encoded conflicting information.

It was also interesting to note that visuospatial ability had an effect only in the active exploration situation. A likely reason for this is that the ability to mentally transform objects is of less relevance when a task merely involves reproducing a map. The navigation task involved mental transformation and manipulation of objects presented on screen, and as such it is to be expected that visuospatial ability would have an effect on the task outcome.

To sum up, the present findings suggest that similar to physical environments and 3D electronic environments, active exploration of a hypertext environment leads to improved knowledge of the environmental configuration compared to passive observation.

Chapter 7

7 Discussion of Overall Findings, Conclusions, and Some Final Thoughts

This research set out to investigate some widely held assumptions concerning navigation in hypertext environments: that it draws on the same principles as navigation in the real, physical world, and that the benefit of metaphors as tools to aid navigation relies on the source domain containing features that typically aid navigation in physical environments. Specifically, this refers to familiarity and spatial characteristics. Furthermore, the work assessed the relevance of a set of individual differences that in previous research had been found to affect how people behave and perform on computer-based tasks in general, and also people's ability and manner of processing information relevant to navigation and formation of internal representations of physical

and electronic environments. These included computer use and confidence; WA cognitive style; and visuospatial ability.

A series of questions were put forward with the purpose of guiding the research. The first question was twofold: Does the metaphor in which a hypertext system is embedded have an effect on navigation and internal representations, and what roles do the spatial and semantic properties of the source domain play? Most importantly, the research showed that in general, metaphor does have an effect on both navigation and internal representations of a hypertext system. However, the exact nature of this effect is more complex than it simply being the case that 'metaphor aids performance'; there are several factors that influence the efficiency of a metaphor. Some relate to the metaphor itself (or its source domain), other to material and task characteristics.

A key area of examination for the research was introduced in a study by Padovani and Lansdale (2003) into the effect of metaphor spatiality on navigation performance and internal representation. The authors concluded that embedding a hypertext system in a metaphor based on a spatial environment (a house) results in improved performance and accuracy

compared to a metaphor without spatial properties (social group), but were cautious about drawing firm conclusions due to the potential confounding effect of familiarity of the source domain. With a theoretical basis in schema theory (e.g. Jonassen & Grabinger, 1990), Study 4 therefore set out to investigate this further by adding to the experimental design a spatial metaphor that did not allow participants to draw on prior knowledge (fictitious town). Findings indicated that the familiar spatial metaphor resulted in improved navigation performance and accuracy compared to the spatial, unfamiliar metaphor, particularly in terms of accuracy of mental representations. Although the findings for navigation performance were not as strong as in Study 4, the results were replicated in Study 5 and Study 6.

The findings from Studies 6-8 identified familiarity and prior knowledge as key determinants of the success of an interface metaphor, however a new question arose as to what aspects of familiarity were more powerful; prior experience (exposure) or prototypicality (Glucksberg & Keysar, 1993). In order to address this question, a metaphor based on a source domain with which the participants were familiar through

experience (the university campus) was added to the design. Findings showed that the prototypical environment (a house) gave superior performance in terms of accuracy of internal representation. For navigation and self-reported disorientation, however, the results showed improved performance for the familiar metaphor (campus). It was suggested that the prototypical metaphor allowed for greater flexibility, which may have slowed down the navigation speed, but allowed for easier integration with schematic representations of prior knowledge.

A further guiding question involved the effect of the nature of the navigation task being carried out. The initial focus in this context was on the effect of prior experience on navigation efficiency. It was assumed that efficiency would be greater in the retrieval phase than in the search phase of the task due to participants having a greater level of experience with the system. Results were, however, not entirely consistent. While the navigation patterns did not differ significantly between the two phases, the time spent per node did. Participants were spending more time per node in the retrieval phase than the search phase of the familiar condition, and vice versa in the unfamiliar condition, suggesting the metaphor had an influence on task

strategy. This pattern could be explained by drawing on research on schematic representations of prior knowledge in relation to decreasing the load on spatial processing (e.g. Arbuckle et al., 1994).

Closely linked to cognitive style research, a further research question concerned the effect of hyperlink structure. Study 5 was based on findings indicating that the structure of the available navigation trajectory, as facilitated by hyperlinks connecting each node, has an effect on performance; and that this effect is mediated by cognitive style (e.g. Calcaterra et al., 2005; Dufresne & Turcotte, 1997; Lee et al., 2005; Liegle & Janicki, 2006; Reed et al., 2000). A 'precursory view' was provided in Study 2, showing that cognitive style was related to hyperlink choice and consequent navigation trajectory. Study 5 built on this by comparing performance and accuracy for hypertext systems with hybrid and linear hyperlink structures. The study did not provide strong evidence for the mediating effect of cognitive style or the effect of hyperlink structure in general. This was most likely due to the linear structure being too restrictive in terms of navigation behaviour, thus failing to elicit 'natural' navigation responses from the participants.

The final guiding question concerned the role of individual differences in relation to measuring navigation performance and accuracy of mental representation. The research focused on two aspects in this context: relevance and metrics. The two aspects individual differences included in the research were WA cognitive style and visuospatial ability. A substantial amount of research has investigated the influence of cognitive style on hypertext navigation. A number of the most cited studies in this area were conducted within the framework of field dependence-independence using the EFT. Because concerns had been raised as to whether the EFT is actually a measure of mental rotation rather than cognitive style (e.g. Griffiths & Sheen, 1992; McKenna, (1984), an examination of the relationship between the EFT measure and visuospatial ability was conducted. Results showed there was indeed an overlap between the two concepts, calling into question the validity of the studies of cognitive style in navigation. A more current cognitive style measure was chosen for the metaphor study series, the ECSA WA (Peterson, Deary, & Austin, 2003b), in addition to a measure of visuospatial ability (Cooper & Shepard, 1973).

The findings for the individual differences variables included in the metaphor studies were inconsistent. The effects that were found were largely on subjective evaluation measures (cognitive workload and perceived disorientation), and not on the navigation or internal representation measures. Apart from potential weaknesses with the instruments themselves, there are two feasible, interconnected explanations for this. As research has shown, hypertext has become a 'genre' in its own right, and as such users have developed schematic representations of the typical features and layout of hypertext systems (e.g. Oulasvirta et al., 2005; Roth et al., 2010). It is likely that, through repeated exposure, individuals who may be at a cognitive disadvantage (e.g. wholists and individuals with low visuospatial ability) have developed compensatory strategies. Thus, as long as the hypertext system adheres to the layout that has become conventional, individual differences do not necessarily affect performance and accuracy.

In terms of the basic assumption that finding your way within a hypertext system is similar to navigating the physical world, and thus draws on the same cognitive resources, providing a direct answer to whether or not this is the case is

beyond the scope of this research. However, some of the results did indicate that some aspects of the navigation experience may be shared. Most concrete were the findings for landmarks. Although the conceptualisation of landmarks differed between the two environments, findings still suggested that people make use of salient features to aid orientation. The other finding that also applies to the physical world is that active exploration leads to a richer and more accurate mental representation of an environment compared to passive exploration.

7.1. Conclusions

In terms of navigation as an experience rather than merely a process, the present findings show that it is important to keep in mind that an individual's subjectively perceived experience may be significantly different from the objectively observed experience. What may be inferred was a 'poor' experience by examining objective measures such as navigation trajectories and time on task, may for the individual undertaking the navigation be just the opposite; or vice versa. Examination of the overall findings makes it tempting to dismiss metaphor as merely a mnemonic device. The effect on behaviour and performance is limited, and most of the use seems to be in facilitating recall of

system structure. However, in a more nuanced view, the findings show that emphasis needs to be placed on the top-down aspect of processing hypertext systems and interface metaphors. In other words, users are relying more on schematic representations of prior knowledge than on immediate perceptual information. When interacting with a familiar domain, bottom-up processing, and consequently individual differences in processing style and ability, becomes less essential. Conversely, in a less familiar system, users will have to rely more on the perceptual information available on the screen, and in this case it is likely that individual differences will have a stronger influence on performance.

On a theoretical level, the findings from the present research suggest that adopting a combination of the field-theoretic framework (Gibson & Crooks, 1982; Gibson, 1986) and the spatial-semantic approach proposed by for example Dillon (2000) for studying electronic navigation (both 2D and 3D) may prove productive. Information presented on-screen is partly perceived directly (such as text layout), and as such the user has to adhere to the environmental constraints. But equally important is the 'shape' the information is given, both in terms of how it fits

with user expectations about the typical structure and conventions of the particular type of environment (such as a website), and users' prior schematic knowledge about the spatial and semantic properties of the domain and any metaphor around which the information is structured. Based on this, a revised version of the conceptual model proposed previously is presented in *Figure 36*.

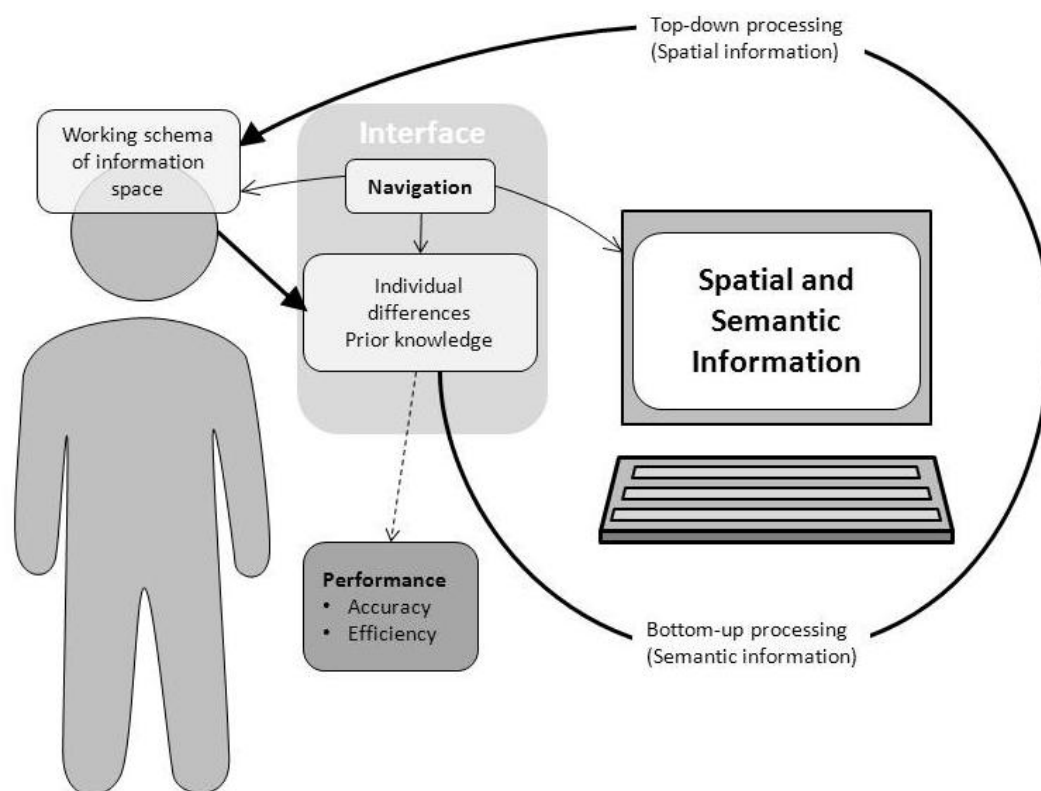


Figure 36. A conceptual model of hypertext navigation based on the present findings

7.2. Implications

Although there seem to be clear advantages to using a metaphor based on a familiar source domain, the findings

suggest that identifying a 'superior' metaphor is not possible. Before choosing to use a metaphor, decisions need to be made as to what constitutes the success of a hypertext system; for example speed or retention of the system contents. In informing design it seems effective metaphors should be based on a source domain that is flexible enough to enable users with different levels of expertise and prior knowledge to integrate the information into their pre-existing schemata without causing too much conflict. Because of the problems that can result from incomplete or inaccurate source-target mapping, care needs to be taken before attempting to fit a metaphor onto a target domain. Certainly, 'shoehorning' information to fit with a metaphor is likely to cause more harm than good. Furthermore, the findings regarding use of landmarks and active exploration may be of relevance to design and also learning within electronic environments. Based on these findings it is possible that static sitemaps are perhaps not optimal when it comes to facilitating mental representation. A dynamic solution may be a more effective way of presenting and learning the structure of an electronic information environment.

In light of the findings concerning the importance of prior knowledge, it is also interesting to note that the individual differences perspective may be less crucial to usability than what has traditionally been put forward in post-1990s research on user-centred design. That is not to say that we should disregard completely the effect of individuals' cognitive abilities and characteristics (also, this does not refer to individual differences that constitute disabilities). When it comes to learning to interact with novel computer systems, individual differences such as visuospatial ability may well be of relevance. However, for a well-established system like hypertext, it is unlikely that user performance will be significantly hampered by relatively minor variations in processing ability.

7.3. Further Investigation

Previous research (e.g. Hsu, 2006; Lee, 2007; Padovani & Lansdale, 2003) into the benefits of metaphor in interaction with computers has often tested the assumption that metaphors are universally beneficial in interaction design. This is clearly not the case; a simple example from the present research is the effect of task type where one metaphor may lead to faster task times, but poorer mental representations. It would be valuable to follow up

the findings concerning different aspects of familiarity (direct experience and prototypicality), particularly in relation to more complex electronic environments, such as for example serious games. Because it seemed the metaphors based on a prototypical source domain may be more robust and flexible, it may be that designers and developers are working within unnecessarily rigid constraints, and that users are more able than assumed to integrate and assimilate new information with their schematic representations.

7.4. Epilogue

In the poem *Caminante no Hay Camino*, Antonio Machado wrote 'se hace camino al andar,' which loosely translates to 'we make the road by walking'. This is quite descriptive of the process of working on this thesis. It is also useful in explaining the logic behind the sequence and order of studies described. In the 20/20 vision of hindsight, there are a few things I would have done differently.

In the early stages of the research, my focus was predominantly on investigating the influence of individual differences on navigation behaviour and performance. As the work progressed, it became apparent that this perspective was

not a very productive one. Individual differences are notoriously difficult to conceptualise and operationalise. It also became clear that the practical relevance of the individual differences measures was limited. The average undergraduate student, the population from which my samples were drawn, has an almost life-long experience with hypertext material. Consequently, variations in cognitive abilities between individuals do not greatly impede or improve their ability to find their way through a hypertext structure. The effect of prior knowledge overshadows any potential effect of individual differences. Allowing a more purposeful investigation of hypertext navigation, my focus shifted from hypertext environments in general to a specific aspect of hypertext; the use of interface metaphors.

Navigating websites is a complex situation, and the nature of the topic warrants a much more refined treatment than the one adopted in the present research. While the individual is still interesting in the context of hypertext use, it is from the point of view of differences in perceived knowledge about environments presented on-screen. A further aspect that could have been approached in a different, and perhaps more subtle, manner is the data analysis. The initial focus on individual differences

resulted in data analyses centred around identifying differences, rather than describing and analysing performance. For example there large disparities are present in the standard deviations of for example the navigation trajectory scores, indicating that while no statistically significant inter-group differences were found, the independent variables clearly had some form of influence on the task outcome. This could have been explored in greater depth. Methodological and theoretical issues notwithstanding, it is my opinion that the work presented in this thesis does represent some contribution to the knowledge in the fields of interaction design and human-computer interaction.

8 Appendices

Appendix A

A1. Ethical approval*

Project Name	Date of Approval
Web design	15 September 2005
Web design, workload and cognitive style	15 September 2005
Spatial Ability Tests	07 November 2006
The Effect of a Social Metaphor and the Influence of Cognitive Style in Electronic Navigation	09 October 2007
The Effect of Familiarity of Metaphor on Hypermedia Navigation	11 September 2008
Familiarity of scenarios	12 January 2009

* All projects were conducted in accordance with British Psychology Society guidelines and approved by the School of Psychology Research Ethics Committee Chair.

Appendix B

B1. Study 2 Materials

Note on website design and coding: The Boots'n'All website was in its entirety designed by the author. This includes graphics, layout, Perl scripts for collecting participant data, and HTML markup. The website can be found in Folder B1 on the attached CD-ROM.

Questions from the Boots'n'all website

Participant no: _____

Please read each question carefully, and indicate the correct answers by ticking the appropriate box. Indicate your level of confidence/awareness by ticking the boxes below each question.

1)	What object is depicted in the site's logo in the top left-hand corner?			
	<input type="checkbox"/> Hat	<input type="checkbox"/> Boots	<input type="checkbox"/> Train	<input type="checkbox"/> Airplane
2)	Which country does Josephine Bloggs describe in her travel article?			
	<input type="checkbox"/> Brazil	<input type="checkbox"/> Honduras	<input type="checkbox"/> Argentina	<input type="checkbox"/> Chile
3)	Where was the winning photo of the Picture of the Month competition taken?			
	<input type="checkbox"/> Cumbria	<input type="checkbox"/> Devon	<input type="checkbox"/> Cornwall	<input type="checkbox"/> Durham
4)	How much can you save using an Air Consolidator Ticket?			
	<input type="checkbox"/> 20-30%	<input type="checkbox"/> 40-80%	<input type="checkbox"/> 10-70%	<input type="checkbox"/> 60-90%
5)	Which of the following was <i>not</i> in the Europe Hotspot list?			
	<input type="checkbox"/> Venice	<input type="checkbox"/> Northern Lights	<input type="checkbox"/> Jersey	<input type="checkbox"/> Isle of Skye
6)	What is the ideal size of a group traveling together?			
	<input type="checkbox"/> Alone	<input type="checkbox"/> 2-3 people	<input type="checkbox"/> 3-4 people	<input type="checkbox"/> 4-5 people
7)	What resolution should photos submitted to Boots'n'all ideally be in?			
	<input type="checkbox"/> 72 ppi	<input type="checkbox"/> 150 ppi	<input type="checkbox"/> 100 ppi	<input type="checkbox"/> 250 ppi
8)	On what street are Boots'n'all's offices?			
	<input type="checkbox"/> High Street	<input type="checkbox"/> Hollow Street	<input type="checkbox"/> History Street	<input type="checkbox"/> Happy Street
9)	In the last joke, what is the old lady at the beach trying to keep dry?			
	<input type="checkbox"/> Hair	<input type="checkbox"/> Cigarettes	<input type="checkbox"/> Shoes	<input type="checkbox"/> Purse
10)	Which of the following was in the content menu in the Women Travelers section?			
	<input type="checkbox"/> Childcare	<input type="checkbox"/> Hygiene	<input type="checkbox"/> Dress sense	<input type="checkbox"/> Safe diet
11)	How many different types of malaria affecting humans are there?			
	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/> 4	<input type="checkbox"/> 5
12)	Which is the best mode of transport when traveling in Europe?			
	<input type="checkbox"/> Car	<input type="checkbox"/> Bike	<input type="checkbox"/> Rail	<input type="checkbox"/> Air
13)	Which charity is promoted at the bottom of each page?			
	<input type="checkbox"/> AMREF	<input type="checkbox"/> UNICEF	<input type="checkbox"/> Amnesty	<input type="checkbox"/> Comic Relief
14)	Which of the following is mentioned as a tip for taking photos at night?			
	<input type="checkbox"/> Doubling shutter time	<input type="checkbox"/> Switch off the flash	<input type="checkbox"/> Use additional light sources	<input type="checkbox"/> Use a tripod
15)	What does Boots'n'all offer members on the Contact page?			
	<input type="checkbox"/> Cheaper rail tickets	<input type="checkbox"/> Free accommodation	<input type="checkbox"/> Free travel guide books	<input type="checkbox"/> Summer jobs

NASA-TLX

Please select (circle) one of each pair of terms that contributed more to the workload (you must select one or the other)

Did the task require:

1. more PHYSICAL DEMAND (physical exertion) or more FRUSTRATION (irritation, felt discouraged)?
 2. more EFFORT (how hard you worked) or more PHYSICAL DEMAND?
 3. more TEMPORAL DEMAND (time pressure) or more FRUSTRATION?
 4. more TEMPORAL DEMAND or more EFFORT?
 5. more EFFORT or was the nature of the PERFORMANCE (success in accomplishing the task) more of a contributor?
 6. more PERFORMANCE or FRUSTRATION?
 7. more PHYSICAL DEMAND or more TEMPORAL DEMAND?
 8. more PHYSICAL DEMAND or more PERFORMANCE?
 9. more TEMPORAL DEMAND or more MENTAL DEMAND (thinking, deciding, remembering etc.)?
 10. more FRUSTRATION or more EFFORT?
- more PERFORMANCE or more MENTAL DEMAND?
 more PERFORMANCE or more TEMPORAL DEMAND?
 more MENTAL DEMAND or more EFFORT?
 more MENTAL DEMAND or more PHYSICAL DEMAND?
 more FRUSTRATION or more MENTAL DEMAND?

Please rate the contributions of each dimension to your task:

MENTAL DEMAND (thinking, deciding, remembering etc.)

Low High

PHYSICAL DEMAND (physical exertion/activity)

Low High

TEMPORAL DEMAND (time pressure)

Low High

EFFORT (how hard you worked)

Low High

PERFORMANCE (success in accomplishing the task)

Poor Good

FRUSTRATION (irritation, discouraged)

Low High

Experimenter To Complete:

SUB-SCALE TITLE	NUMBER OF TIMES SCALE CIRCLED - WEIGHTING	RAW RATING GIVEN	ADJUSTED RATING = WEIGHTING X RAW RATING
MENTAL DEMAND			
PHYSICAL DEMAND			
TEMPORAL DEMAND			
EFFORT			
PERFORMANCE			
FRUSTRATION			

WEIGHTED RATING = (Sum of Adjusted Ratings) divided by 15 =

B2. Study 2 Results: See attached CD-ROM (SPSS Output)

Appendix C

C1. Study 3 Materials

Santa Barbara Sense of Direction Scale

Student ID: _____

Sex: F M

Part. No.: _____

Age: _____

This questionnaire consists of several statements about your spatial and navigational abilities, preferences, and experiences. After each statement, you should circle a number to indicate your level of agreement with the statement. Circle "1" if you strongly agree that the statement applies to you, "7" if you strongly disagree, or some number in between if your agreement is intermediate. Circle "4" if you neither agree nor disagree.

1. I am very good at giving directions.
strongly agree 1 2 3 4 5 6 7 strongly disagree

2. I have a poor memory for where I left things.
strongly agree 1 2 3 4 5 6 7 strongly disagree

3. I am very good at judging distances.
strongly agree 1 2 3 4 5 6 7 strongly disagree

4. My "sense of direction" is very good.
strongly agree 1 2 3 4 5 6 7 strongly disagree

5. I tend to think of my environment in terms of cardinal directions (N, E, S, W)
strongly agree 1 2 3 4 5 6 7 strongly disagree

6. I very easily get lost in a new city
strongly agree 1 2 3 4 5 6 7 strongly disagree

7. I enjoy reading maps.
strongly agree 1 2 3 4 5 6 7 strongly disagree

8. I have trouble understanding directions.
strongly agree 1 2 3 4 5 6 7 strongly disagree

9. I am very good at reading maps.
strongly agree 1 2 3 4 5 6 7 strongly disagree

10. I don't remember routes very well while riding as a passenger in a car.
strongly agree 1 2 3 4 5 6 7 strongly disagree

11. I don't enjoy giving directions.
strongly agree 1 2 3 4 5 6 7 strongly disagree

12. It's not important to me to know where I am
strongly agree 1 2 3 4 5 6 7 strongly disagree

13. I usually let someone else do the navigation planning for long trips
strongly agree 1 2 3 4 5 6 7 strongly disagree

14. I can usually remember a new route after I have travelled it only once
strongly agree 1 2 3 4 5 6 7 strongly disagree

15. I don't have a very good 'mental map' of my environment
strongly agree 1 2 3 4 5 6 7 strongly disagree

Appendix D and E

See attached CD-ROM (SPSS Output)

Appendix F

F1. Study 6 Materials

Web Orientation Questionnaire	
Student ID: _____	Sex: F M Age: _____
<p>This questionnaire consists of several statements about your sense of orientation using a website. After each statement, you should circle a number to indicate your level of agreement with the statement. Circle "1" if you strongly agree that the statement applies to you, "7" if you strongly disagree, or some number in between if your agreement is intermediate. Circle "4" if you neither agree nor disagree.</p>	
1. I felt lost	strongly agree 1 2 3 4 5 6 7 strongly disagree
2. I felt like I was going around in circles	strongly agree 1 2 3 4 5 6 7 strongly disagree
3. It was difficult to find a page that I had previously viewed	strongly agree 1 2 3 4 5 6 7 strongly disagree
4. Navigating between pages was a problem	strongly agree 1 2 3 4 5 6 7 strongly disagree
5. I didn't know how to get to my desired location	strongly agree 1 2 3 4 5 6 7 strongly disagree
6. I felt disoriented	strongly agree 1 2 3 4 5 6 7 strongly disagree
7. After browsing for a while I had no idea where to go next	strongly agree 1 2 3 4 5 6 7 strongly disagree

Questionnaire adapted from Ahuja, J.S. & Webster, J. (2001). Perceived disorientation: an examination of a new measure to assess web design effectiveness. *Interacting with Computers*, 14, 15-29.

Appendix G

See attached CD-ROM (SPSS Output)

9 References

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9.1. Publications Resulting From This Thesis

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