Expertise in Map Comprehension: Processing of Geographic Features according to Spatial Configuration and Abstract Roles

Robin S.G. Kent

Submitted for the degree of DPhil
University of Sussex
November 2010

Declaration

I declare that this thesis has not been submitted in whole or in part to this or any other University for the award of a degree.

Robin Kent

Acknowledgements

I am particularly grateful to my first supervisor, Professor Peter Cheng, whose professional advice and patience has guided this research from inception to completion. It has been a privilege to work with someone so dedicated to promoting the Research interests of his department, while providing unfailing support to his students.

I would also like to thank Dr. Clare Davies and the research team at Ordnance Survey for providing very helpful cartographic inputs during the development of the experimental designs.

I am also grateful to my second supervisor Dr Richard Cox and for the essential funding and facilities provided for this research by the University of Sussex, the ESPRC and the Ordnance Survey UK.

I thank also the past and present members of the Representation and Cognition Laboratory at the University of Sussex for their valued humour, friendship and very helpful assistance throughout the early pilot studies for this research and latterly during the analyses.

Finally I thank my wife Antoinette for the huge support and encouragement she has given me in this and the many other life challenges we have shared.

Expertise in Map Comprehension: Processing of Geographic Features according to Spatial Configuration and Abstract Roles

Abstract

Expertise in topographic map reading is dependent on efficient processing of geographical information presented in a standardised map format. Studies have supported the proposition that expert map readers employ cognitive schemas in which prototypical configurations held in long term memory are employed during the surface search of map features to facilitate map comprehension. Within the experts' cognitive schemas, it is assumed that features are grouped according to spatial configurations that have been frequently encountered and these patterns facilitate efficient chunking of features during information processing.

This thesis investigates the nature of information held in experts' cognitive schemas. It also proposes that features are grouped in the experts' schemas not only by their spatial configurations but according to the abstract and functional roles they perform.

Three experiments investigated the information processing strategies employed by firstly, skilled map readers engaged in a map reproduction task and secondly, expert map readers engaged in a location comparison exercise. In the first and second experiments, skilled and novice map readers studied and reproduced a town map and a topographic map. Drawing protocols and verbal protocols provided insights into their information processing strategies. The skilled map readers demonstrated superior performance for reproducing contour related data with evidence of the use of cognitive schemas.

For the third experiment, expert and novice map readers compared locations within map excerpts for similarities of boundary extents. Eye-gaze data and verbal protocols provided information on the features attended to and the participants' search patterns. The expert group integrated features into their cognitive schemas according to the abstract roles they performed significantly more frequently than the novices. Both groups employed pattern recognition to integrate features for some of the locations. Within a similar experimental design the second part of the third experiment examined whether experts also integrated the abstract roles of remote features and village grouping concepts within their cognitive schemas. The experts again integrated the abstract roles of physical features into their schemas more often than novices but this strategy was not employed for either the remote feature or grouping categories.

Implications for map design and future Geographic Information Systems are discussed.

Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

1.1 Chapter Outline

In this opening chapter a brief summary of previous research in cognitive cartography is provided together with an appraisal of some of the related methodological and theoretical considerations. This is followed by a description of the research reported in this thesis and the scope of the experimental studies. The research questions addressed in this study are then described and the chapter concludes with an overall structure of the thesis.

1.2 Historical Perspective

The design and production of maps are activities that both reside comfortably in the domain of cartography. However the reading and comprehension of maps is not so easily classified within a single discipline. A human map user requires at least some knowledge of the principles of cartography but individual performance will be dependent on a far wider range of skills such as spatial abilities, geographical knowledge, familiarity with the task and overall cognitive abilities. Unsurprisingly therefore, studies which include an experimental task of map reading have been conducted within a number of disciplines beyond cartography. These have included experimental and cognitive psychology, the social sciences, artificial intelligence and more recently the science of Geographic Information Systems (GIS).

The importance of the role of the map reader in a task of map interpretation has been highlighted by Mark Blades and Christopher Spencer (1986). In a seminal paper these authors reflected the views of a number of their peers (Eastman & Castner, 1983; Gilmartin, 1986; Olson, 1979) and called for a more disciplined approach to cartographic research in which the act of interpreting a map was to be treated as a cognitive task in which precise and testable predictions might be examined. This emergent discipline is now widely acknowledged under the title of cognitive cartography and has been described by Montello (2002) as three separate areas of research.

The first research area has as its goal the design and eventual improvement of current map presentations and studies in this domain are conducted largely by academic cartographers.

In the second area the aim is to research the educational aspects of map use and is more closely aligned to educational geography and the acquisition of knowledge about maps and map usage. Studies in this area are generally conducted by developmental psychologists and educational researchers.

The third area is described as map-psychology research and includes studies on the cognitive processes employed during map study such as cognition, memory and perception. Research in this area is predominately conducted by psychologists.

These three fields of research are now considered in turn. Map design is the first of these areas and has had the most influence on the cartographic community. Within this domain researchers have examined the effectiveness of map design (Artez, 1991; Castner, 1983; MacEacheren, 1995; Monmonier, 1996; Slocom & Egbert, 1993; Tversky, 2000), investigated the interactive qualities of maps (Barkowsky & Freksa, 1997; Wood, 1992; 1993) and researched how maps are used (Blades & Spencer, 1986; Garling & Golledge, 2001; Levine, 1982). More recently some of the theoretical considerations for GIS development have also been studied (Davies, 2002; Davies & Medyckyj-Scott, 1996; Montello & Freundschuh, 2005; Wood, 2003).

The second area of research within the cognitive cartography discipline covers the educational and developmental perspectives of map comprehension. With studies of children's abilities to comprehend simple maps from early kindergarten through to adolescence this field of research has benefited for the last twenty years from the influential work of Lynn Liben and Roger Downs (Downs, 1985; Liben & Downs, 1989, 1994; Liben & Downs, 2003). Together with a number of developmental researchers (Freundschuh, 1990; Wallace & Almy, 1999) Liben and Downs have conducted research into how spatial cognition, concepts of space and map comprehension develop in children within the associated disciplines of geography, education and psychology.

In the third research area psychologists have employed maps as the experimental stimuli or observed participants in map reading tasks in order to study a variety of cognitive processes. These have included: the cognitive construction of spatial mental models (Lee & Tversky, 2005; Taylor & Tversky, 1992); sex-related differences in the processing of geographic information (Gilmartin, 1986; Montello, Lovelace , Golledge,

& Self, 1999); mental rotation in orientation tasks (Gunzelmann & Anderson, 2006; Gunzelmann, Anderson, & Douglass, 2004) and; cognitive abilities employed in way-finding (Cornell & Heth, 2001; Cornell, Sorenson & Mio, 2003; Crampton, 1992). More recently neuropsychologists have used fMRI studies to study the brain structures associated with spatial information processing (Hartley et al., 2007; Rosenbaum, Ziegler, Winocur, Grady, & Moscovitch, 2004). Most pertinently for the current study, the cognitive strategies and information processes used by skilled map users when studying and memorizing map presentations have been examined (Gilhooly, Wood, Kinnear, & Green, 1988; Postigo & Pozo, 1998; Thorndyke & Hayes-Roth, 1982; Thorndyke & Stasz, 1980). These latter studies, which relate directly to information processing strategies, are examined in more detail in the following chapter.

1.3 Nature of Research in this Thesis

The research in this thesis investigates the nature of expertise in map comprehension. Specifically it is a study of the information processing strategies employed by experienced map readers when studying geographic features represented in topographic maps. Earlier research has suggested that experienced map readers might employ cognitive strategies to integrate geographic features into information ‘chunks’ during encoding and thereby facilitate processing. However, none of the previous studies attempted to identify which features were grouped or the criteria adopted to categorise features into groups.

The three experiments conducted within this study therefore had two aims. The primary aim was to establish that the experienced map readers were processing geographic features within cognitive schemas commensurate with the information processing strategies employed by experts operating in other domains. The secondary aim was to attempt to identify which features were integrated into schemas during encoding and how the features may have been categorised. As a study of information processing and expertise, this research therefore resides at the centre of the map psychology research area in the cognitive cartography spectrum discussed above.

However, while geographic information has traditionally been recorded on paper maps, it is now increasingly presented using electronic displays such as GIS. This study employed paper maps and a desk-top display but provided an opportunity to consider how conventional map-reading expertise might also relate to the skills required by today's GIS operators. Since the findings from this research have implications for the design of both maps and GIS applications, it additionally contributes to the map design area of cognitive cartography.

The first two experiments in this study investigated how skilled and novice map users processed contour-related information during study and recall of a topographic map. Both experiments identified differences between skilled and novice map readers in their ability to integrate individual features with contour data and provided evidence that suggested that skilled map readers employed cognitive strategies to assist in the processing of contour-related information.

The third experiment in this thesis continued the investigation into the information processing techniques employed by experienced map readers but focused on how experts might integrate map features during processing. It was hypothesized that expert map readers process geographic and man-made features presented in a map display in two fundamentally different ways. Firstly, experts may process features within familiar spatial configurations which represent prototypical locations having similar integrated and related features or sharing similarities in feature layout. Secondly, however, they may also employ their knowledge of the functions performed by the features to provide enhanced understanding of the location they are studying and, as a result, process within their cognitive schemas features according to their functional relevance.

Accordingly, geographic and man-made features adjacent to urban locations were selected which had both a spatial relationship with the location but also a functional role if they formed a physical boundary. Identification of these functional roles required a level of expertise and when set as an experimental task provided both the facility to differentiate between expert and novice map-reading performance and a method of examining how experts might integrate geographic features during encoding. In addition, this experiment incorporated research aims which have particular relevance to a broader study of the concept of 'place' presently being undertaken by the research team at Ordnance Survey UK.

The definition of how far a place extends is seldom a simple cognitive construct. The outer boundaries of a town or village may be determined by geographic or man-made features but may encompass concepts such as 'vernacular geography' in which informal understandings of boundary extents evolve within local communities. Places are also occasionally defined by indeterminate or ‘fuzzy’ boundaries which delineate outer limits according to subjective classifications, historical perspectives or administrative considerations. Vagueness and subjectivity in defining the extents of places may be ignored or only loosely defined on a paper map but the lack of crisply defined boundaries presents a particular problem for GI systems where the inclusion or exclusion of features within a computer-defined area often requires dichotomous decision-making by the system programmer. Where place extents may have been represented in a generalised format by earlier cartographers many GIS applications now require much greater levels of precision during the production of spatial data sets.

The insights provided by the third experiment into how expert map-readers evaluate features associated with urban locations are therefore also considered for their contribution to current research on the definition of place extents.

1.4 Scope of Research

This thesis is concerned in general with expertise and in particular with the information which is processed in the cognitive schemas of skilled topographic map readers as they process geographic data in real-time. It is not a dedicated study of perception, spatial memory or visual attention and examines these cognitive processes only for their contributions to expertise in a map comprehension exercise.

The acquisition of expertise in any domain is dependent on a number of considerations and these are examined in the literature review in Chapter 2. These include, deliberate practice, cognitive abilities, domain knowledge and task familiarity, all of which make some contribution to expert performance. These aspects of expertise are accounted for but not specifically researched within this thesis. Instead the research is focused on the cognitive processing of geographical features in map comprehension tasks.

The map exercises employed for each experiment do not involve components of self-location, way-finding or map orientation and the tasks are designed intentionally to minimise any possible gender effects.

1.5 Research Questions

The primary research question addressed by this thesis is: What is the nature of the information processing strategies employed by experts in map reading and comprehension? For each of the three reported experiments, however, eight specific questions relating to the nature of information processed for each of the experimental tasks were examined in turn.

In Experiment 1 the participants were required to study and reproduce firstly a non-contour map and then a topographic map. Two questions were posed to assess whether the skilled group had better recall of information relating to their specialist knowledge.

1. *Do experienced map readers have better recall for map information than less experienced map users?*
2. *Do skilled contour map readers have a superior memory advantage for both contour and non-contour information?*

Two further questions were framed to investigate the participants' use of information processing strategies.

3. *Do experienced map readers employ cognitive strategies such as information chunking during encoding and recall of map information?*
4. *Do experienced map readers employ cognitive strategies such as the use of templates to assist in the processing of spatial information presented on a map?*

Experiment 2 repeated the research in Experiment 1 within a modified experimental design but again addressing research questions 1 to 4.

With evidence from the first and second experiments that skilled map readers had employed cognitive schemas in the map study and recall task, the third experiment provided Expert and Novice groups with a boundary identification task. The participants studied map excerpts of town and village locations presented as *probes* and then judged the similarity of their boundary extents to those in the *distractor* and *target* locations. For the first part of this study, Experiment 3a, the primary research question again investigated the experts' use of cognitive schemas but the following two questions specifically addressed how the geographic features were processed.

5. Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping features according to familiar patterns?

6. Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping features according to abstract roles?

The second part of the third study, Experiment 3b, employed a similar experimental design to Experiment 3a, but introduced remote features and grouping concepts as entities which might have extended the perceived location boundaries. The last two research questions examined in Experiment 3b were as follows.

7. Do expert map readers integrate the abstract roles of remote but associated features within their schemas of what constitutes the outer extent of a locality?

8. Do expert map readers integrate the abstract roles of conceptual grouping features into their schemas of what constitutes the extent of the community boundaries?

1.6 Thesis Structure

Following this introductory chapter a detailed literature review is provided in Chapter 2 in which the concept of expertise and its acquisition is examined in a number of domains and then in more detail as it might apply to the tasks of map reading and comprehension.

In Chapter 3 the first experiment is reported. This experiment replicated an earlier study by Thorndyke & Stasz (1982) in which skilled map readers were compared with novices in a map studying and copying task. The purpose of this piece of research had been to identify the cognitive strategies employed by the skilled map readers as they processed the topographical map data and has also been reported as a published paper (Kent & Cheng, 2008), provided at Appendix 1. In the second experiment, described in Chapter 4, an improved experimental design was introduced to address a number of shortcomings identified in Experiment 1. The research aims for the second experiment remained identical to those investigated in the earlier experiment.

For Experiment 3a, reported in Chapter 5, a group of expert map readers were compared with a novice group in a task of comparing locations for perceived similarities in their boundary extents. The research questions examined whether expert map readers processed geographic features according to their spatial configuration or according to their abstract and functional roles.

The second part of this experiment, Experiment 3b, is reported in Chapter 6. This study expanded the research question relating to the processing of abstract roles of geographical features to include remote but associated features and grouping concepts which might be judged to extend the location boundaries. Again, the focus of the research had been on the nature of information processing employed by the expert group.

The first two experiments in this study therefore replicated and validated earlier work in the study of map-reading expertise. The third experiment, however, provided a novel demonstration that expert map readers employed information processing strategies in which geographic features were processed according to both familiar spatial configurations and the abstract roles they might have been performing.

The conclusions of the thesis are provided in Chapter 7 together with a discussion on the implications of the findings for future research.

Chapter 2: Review of the Literature Relating to Theories of Expertise

2.1 Introduction

In this chapter a number of theoretical approaches to the acquisition of expertise are examined. Although expertise is highly specialised within each domain and comprises attributes of skill unique to the area of competence, there are nevertheless commonalities in how expertise is developed and maintained across the various specialisations. Theories which describe the improved processing of information observed in experts are considered for their relevance to the development of expertise in map comprehension.

2.2 Information Chunking and Template Theory

2.2.1 The nature of expertise

Experts operating within their areas of expertise consistently outperform novices engaged in similar tasks by demonstrating greater subject knowledge and decision-making competence than non-experts. Through practice they acquire cognitive skills that enhance their ability to process domain-relevant information more efficiently and effectively.

Accounts of expertise have attempted to provide descriptions of the altered cognitive functioning in experts within a number of paradigms. These have included Chunking Theory (Chase & Simon, 1973a) and an associated study of perception in chess by the same authors (1973 b), Template Theory (de Groot & Gobet, 1996; Gobet, 2005), Long Term Working Memory Theory (Ericsson & Kintsch, 1995), Deliberate Practice Theory (Ericsson, Krampe, & Tesch-Romer, 1993) and the Theory of Expert Competence (Shanteau, 1992). Each of these theoretical approaches enhances our understanding of the acquisition of expertise. In this chapter, however, they are examined in the context of their contribution to accounts of expertise in map reading and comprehension.

2.2.2 Chunking theory

An early pioneer of expertise in chess research Adriaan de Groot (de Groot, 1965; de Groot & Gobet, 1996) observed that chess Masters after studying a board for 5 seconds could recall almost 25 separate pieces while less experienced players recalled only five. The latter number corresponds to about the same number of items that can be maintained in Short Term Memory (STM). In replicating the experiments of de Groot, Chase and Simon (1973a) formulated the first general theory of expertise by proposing that expert memory in chess was achieved by 'chunking' the observed deployment of pieces into familiar board patterns involving groups of pieces. Chase and Simon's important contribution was to re-evaluate their expert's performance with random positioning of pieces on the chessboard. Here the experts fared no better than the novices.

The authors concluded, therefore, that experts had similar constraints as novices on the number of remembered items in short-term memory but the information contained in each 'chunk' was of far greater complexity because it represented a familiar configuration of pieces (Chase & Simon, 1973 b; de Groot & Gobet, 1996).

2.2.3 Extensions of Chunking theory

Further expertise research in alternative domains has found support for the Chase and Simon paradigm. Expert bridge players (Charness, 1979) recalled dealt card distributions by grouping each hand into suits and from three hands inferred the fourth. Novice players attempted to remember each card in the order of card value. Similarly, electronics engineers have been shown to recall the layout of individual components as functional elements of larger circuit configurations when they are presented in an authentic electronic circuit diagram, while novices recount only the spatial positioning of components during recall (Egan & Schwartz, 1979).

2.2.4 Problems with Chunking theory

However, Chunking theory suffers from a number of weaknesses. It focuses on the limitations of STM and assumes that information encoding into Long Term Memory (LTM) is relatively slow, even with experts (Chase & Ericsson, 1982). It predicts that interference with short-term memory processes will affect expert performance. In practice this does not occur in every case and studies where participants completed interference tasks to prevent rehearsal of chess positions held in STM showed that subsequent recall from LTM was unaffected (Charness, 1976). Also the theory does not account fully for the high-level, schematic knowledge often employed by experts during problem solving (Gobet, 2005).

2.2.5 Template theory

To address these shortcomings Gobet & Simon (1996) proposed the Template theory. The authors suggested that 'chunks' that appear frequently in a chess player's experience eventually evolve into more complex structures forming schematas or templates. Since templates might contain strategic information as well as the tactical data of recent moves, information can be matched and stored in LTM more rapidly. Also, templates may be linked to provide the 'meta-search' procedures employed by chess masters during forward search, while information held in templates facilitates accurate and rapid recollection of items after memory decay in STM (Gobet, 1997).

2.2.6 CHREST computer models

Template theory has provided the theoretical basis for CHREST (Chunk Hierarchy and Retrieval Structures) a computer program incorporating a STM, a LTM indexed by a discrimination net and a simulated eye (Gobet & Charness, 2006). Using CHREST, extended simulations of chess skill acquisition have demonstrated that templates can be acquired incrementally and automatically and these provide the mechanisms for rapid encoding of information into LTM (Gobet, 2005). Within the CHREST programme, eye movements have been simulated to model behaviour in which the nature of the perceived information determines what is learnt. More importantly, that which has been learnt governs what will be perceived in future searches (Gobet & Charness, 2006).

The integration of perceptual information with structured information held in memory is an essential feature of the acquisition of rapid, forward-search patterns employed by expert chess players. It also provides the explanation for the acquisition of knowledge structures attributed to experts in other domains that incorporate an active top-down processing component (Durso & Dattel, 2006).

2.2.7 Variations on Chunking theory

However, while there is considerable agreement within the Cognitive Science community on the value of chunking information to both facilitate information processing and to overcome the limitations of STM, there is debate on the nature of information held within the chunks. Linhares & Brum (2007) propose an alternative to the description of information processing described by Gobet & Charness (2006).

Where Template theory and its practical prodigy the CHREST computer model both describe the construction of templates from chunks containing familiar patterns of chess pieces, Linhares & Brum propose that expert chess players encode chess pieces and groups of pieces according to their abstract roles. Within this description, recalled chess pieces need not be in close proximity or arranged in a recognizable pattern. Instead, experienced players perceive a chess piece or group of pieces in terms of the abstract role performed by the individual pieces within the board configuration.

The pieces in play might even be dissimilar. A knight moving to check a king while also threatening the opponent's rook would create an 'absolute fork'. A bishop might create a similar threat along a diagonal, threatening the king and a rook by creating a fork with an entirely different set of adjacent pieces and in a different board location. In such cases, both the knight and the bishop perform similar abstract roles and might be encoded or recalled as comparable chunks without any associated pattern matching.

The Linhares & Brum hypothesis is in accord with the findings of an influential study of expertise by Chi, Feltovich, and Glaser (1981). These authors tested their participants with a set of physics problems and reported that the novice group paid excessive attention to the surface features of a problem whereas experts were able to point out the basic physics principle underlying each problem. Novice physics students tended to classify the types of problems by their surface similarity with descriptions such as 'arrangements of pulleys', 'velocity problem' and 'inclined plane'. On the other hand, expert physicists tended to classify the problems by describing the underlying physics principles involved, such as 'conservation of energy' or 'Newton's third law' regardless of their surface structure.

Thus pattern matching, as described in Template theory, may indeed be one strategy employed for the encoding of information into chunks but, as Linhares & Brum suggest, the use of abstract roles is an alternative strategy which may be more relevant as levels of expertise increase.

2.2.8 Chunking and map reading

Whether chunks are generated from visual patterns or abstract roles, Chunking theory and its more comprehensive successor, Template theory, provide detailed accounts of how information processing is facilitated in experts by the use of schemas.

In a map reading task where the map corresponds to a known landscape, experts might be expected to encode it not just as separate 'chunks', but within an overall template that incorporates the relationships between the groups of objects viewed (Davies, 2005; McGuinness, 1994). Specifically experts may be: 1. Focusing on the distinctive features of a display to establish how it may differ from the norm; 2. Identifying what is familiar and typical and which therefore requires minimal processing; and 3. Performing both spatial feature-matching of the geometric or symbolic information provided on the map with geographic feature-matching in the landscape being represented (Chang, Antes, & Lenzen, 1985). Three early studies on the nature of expertise in map reading tasks have suggested that the employment of 'information chunking' strategies during the encoding and retrieval of spatial information may contribute to improvements in map comprehension and recall for experienced map users.

2.2.9 Evidence of chunking strategies in map tasks

Thorndyke & Stasz (1980) examined novices and experts engaged in encoding and recalling information from firstly a prototypical town map and secondly a fictitious countries map. Since their maps contained both spatial and verbal information the researchers predicted that participants might employ different encoding strategies such as information chunking (Newell & Simon, 1972) and dual-coding techniques (Paivio, 1971) to integrate the verbal and spatial data.

Although Thorndyke and Stasz failed to demonstrate that previous experience with maps was a predictor for successful learning of map data, the 'good learners' in their experiment employed four specific techniques during map study to assist encoding and recall of spatial information. These the authors categorised as: *relational encoding* - combining the spatial relationships of two or more features; *pattern encoding* - matching features within a geometric pattern; *labelling* - generating a verbal cue to recall complex spatial configurations and *visual imagery* - constructing mental images to memorize the data. Several of their map readers also demonstrated the use of *schema* *application* where information was encoded as it related to a pre-existing prototypical configuration held in Long Term Memory. Although the results from this study suggested that learning strategies and visual memory ability were more reliable predictors of performance in map recall than previous experience, perhaps the more relevant finding was that the experienced map readers differed from the novices by their more frequent use of information processing techniques similar to those predicted by Chunking and Template theories.

In a later study (Gilhooly et al., 1988) the authors suggested that Thorndyke & Stasz's failure to establish a clear relationship between expertise and memory for maps had resulted from their use of planimetric (non-contour) maps. When Gilhooly and his colleagues employed contour maps in a similar experimental design to the earlier study, skilled map readers showed superior memory skills for the topographical material.

By the use of protocol analysis during both the encoding and recall phases Gilhooly et al were able to identify their experts' employment of specialist schemas in which single features were encoded as entities within a familiar group of related items. The experienced map readers also paused less often during recall prompting the authors to suggest that their skilled participants retrieved larger chunks of information. Gilhooly et al. summarised their findings by proposing that 'skilled map readers have a rich repertoire of schemata that are used in encoding information from a contour map' (p107), thereby endorsing the relevance of both the Chunking and Template theories to any study of expertise in map reading and comprehension.

In a third study of expertise in contour map reading tasks Chang, Antes & Lenzen (1985) studied eye movements of both experienced and novice map readers. The authors found that experts had shorter fixations on contour related features suggesting easier processing of the information during the integration of contour data into the experts evolving schemas. Experts were therefore more adept at transforming a two-dimensional representation of contour data into a three-dimensional mental image of the terrain depicted. However, when the experts were confronted with irregular topographical information or random contour lines the experts' visual search times increased as they struggled to make meaningful patterns from atypical representations. These results mirrored the additional cognitive processing observed when chess masters recalled random piece positioning from unstructured board layouts in the Chase & Simon (1973a; 1973b) literature.

2.2.10 Summary of Chunking theory and Template theory

These two theories therefore provide relevant accounts of how experts might generate and employ schemas during the processing of geographic data. Within these schemas familiar patterns of features could be held in templates to allow forward searching for matches to, or variations from, a prototypical configuration defined by the schema in use. Information processing would be faster because groups of features could be inferred from the processing of a unitary feature. Similarly, Short Term Memory constraints would be avoided by incorporating more elaborate sets of data within each information chunk.

Yet while this account of cognitive processing in experts is pivotal to the discussion and research reported in this paper, it is readily acknowledged that the acquisition of expertise is a highly complex process that encapsulates more than the employment of altered cognitive processing. Some of these considerations are addressed in the theories of expertise examined further in this chapter for their relevance to skill in map-reading tasks.

2.3 Long Term Working Memory Theory

As described in the earlier sections, information chunking and pattern matching are key features of Simon and Newell's chunking theory. Both these concepts are retained in Ericsson & Kintsch's (1995) Long Term Working Memory (LTWM) theory. However, these authors suggest that information is not transferred from Long Term Memory (LTM) by the use of templates. Rather, practised recall of familiar information from LTM is achieved by the use of retrieval cues accessing information held in Long Term *Working* Memory. Items of information being processed in Short Term Working Memory (STWM) remain unaffected by a distraction task (Charness, 1976) since all recently processed data can be instantly reinstated from LTWM. Individuals working in their area of expertise develop retrieval structures to access stored information in LTWM thereby overcoming the known limitations of retaining information in working memory.

In examining the relevance of LTWM Theory to expertise in map usage it is important to note that LTWM Theory, like Template theory, proposes pattern recognition as the procedure that determines at the outset which retrieval structure is to be employed. The two theories differ predominantly in their descriptions of how increased information flow between Short Term and Long Term Memory is achieved and whether templates or an extension to STWM can provide the explanation. This distinction does not materially affect the pattern recognition and information chunking processes inherent in both descriptions. Indeed, Fernand Gobet, the original proponent of Template theory, affords each theory equal recognition in a recent summary of studies of chess expertise by suggesting that 'experts rely on a rich network of chess patterns stored in Long Term Memory structures (or Long Term Working Memory) to give them a larger visual span when encoding chess positions' (Gobet & Charness, 2006, p526).

2.4 The Role of Deliberate Practice

Ericsson et al (1993) identified deliberate practice as the key activity in the acquisition of expertise in violinists and pianists. Violin players, rated by their music academy as their best musicians, had accumulated on average 7,500 hours of solitary practice by their eighteenth birthday. For the violinists rated only as 'good' the total hours of deliberate practice was of the order of 5,300. The pattern was more marked in the accompanying study of pianists with the expert players achieving over 7600 hours of deliberate practice by the age of eighteen against the average of 1600 hours estimated by the competent amateur players.

Neil Charness (Charness, Krampe, & Mayr, 1996) studied chess players' attendance at international tournaments and frequency of coaching sessions and established that solitary study and move rehearsal were the most powerful predictors of skill levels in experienced players. In a later experiment Charness working with a different set of researchers (Charness, Tuffiash, Krampe, & Reingold, 2005) found that chess Grandmasters spent over 5000 hours of chess-related study in the first decade of serious competition. This figure represented five times the average amount reported by less skilled intermediate players. Again the amount of deliberate practice predicted the level of skill achieved in their participants with greater reliability than any of the associated factors.

Although several of the theories of expertise examined earlier in this paper and again in this section have focused on the domain of chess, Gobet (1998) has observed that the three primary features of chess expertise (i.e. selective search, memory for meaningful material and the importance of pattern recognition) are relevant to other domains. All three of these elements of information processing have been shown to influence skill in map reading tasks (Eccles, Walsh, & Ingledew, 2006; Gilhooly et al., 1988; Thorndyke & Stasz, 1980). If the information processing of chess players is similar to that employed by map users and deliberate practice is the single most important factor in the development of expertise in chess players, then a similar relationship between skill in map use and dedicated practice with maps should be evident.

However, here we encounter one of the major shortcomings of research into expertise in map reading. The categorisation of expert within a number of cartographic and psychological studies has all too often been based arbitrarily on the profession or current employment of each participant. Often this has been without a clear evaluation of the level of expertise. Indeed, it is highly unlikely that any of the participants in any of the map reading experiments examined in this paper could meet the very demanding criteria of deliberate practice in terms of hours of study or skill levels that distinguished the musicians studied by Ericsson (1993) or the chess players observed in the Charness et al (1996) and Charness et al (2005) studies.

2.4.1 Deliberate practice and map reading skill

Within this literature review no studies of expertise in map reading have been identified that specifically researched the role of deliberate practice. In view of the similarities already identified between the pattern recognition processing employed in chess and map reading, this finding was surprising. However, three possible explanations are now considered. Firstly, the levels of expertise in chess players can be accurately defined and evaluated. Grandmasters have an Elo rating (Elo, 1986) above 2400 while Expert level is defined as above 2200. These ratings are based on a sophisticated measurement system incorporating individual experience and recorded performance levels. No equivalent evaluation of map reading expertise has been developed and therefore levels of skilled performance have not been independently evaluated within the participants recruited for map reading experiments.

Secondly, the discipline and dedication of professional chess players involves considerable allocation of time to chess-related study. Expert map readers are unlikely to have dedicated similar resources of time to the study of maps. Nor is it likely that map enthusiasts could reconstruct accurately how much time has been allocated to map tasks over an extended period in the way that chess experts are able to do. Measurements of the overall time allocated to the acquisition of expertise in map usage, apart perhaps from the more general measure of number of years experience in map use, are therefore unlikely to incorporate genuine empirical validity.

Finally, the wide variety of applications associated with map usage involves diverse goals and task demands. Coupled with the reported lack of uniformity in the procedures employed for many of these differing tasks, comparisons of performance are likely to be affected by a large number of confounding variables. Meaningful estimations of the true effect size of deliberate practice as a predictor of skill in map reading would therefore be unreliable in any discipline which lacks the rigour of skilled performance measurement already established in the domains of chess and music. The importance of task characteristics and their effect on skilled performance are addressed more fully in the Theory of Expert Competence considered in the following section.

2.4.2 Summary of the role of deliberate practice

Deliberate practice, then, is crucial to the acquisition of expertise in a number of domains. It reliably distinguishes expert performers from competent but less dedicated chess players and musicians. To achieve the standards of excellence associated with chess Grandmasters or virtuoso musicians, students must devote thousands of hours to deliberate practice over periods of ten or more years. This practice will have included structured monitoring and analysis of performance to identify and overcome weaknesses and repeated rehearsal of difficult passages or game-plans to identify solutions (Ericsson et al., 1993). In short, domain experience alone did not distinguish experts from the less proficient groups but the effortful and deliberate practice did.

As we have noted, the role of deliberate practice in map-related tasks has not been adequately addressed in most of the studies to date (Davies, 2005). The usual criteria employed to differentiate participants by ability has been based on task experience. As demonstrated in the research above, overall experience is a necessary indicator of good performance but it may be insufficient as a predictor for expertise. Further factors influence overall competence in any task and these are now considered in the following section.

2.5 The Theory of Expert Competence

The theories considered so far have attempted to provide explanations of expertise within a framework of the subtle cognitive adaptations that experts develop to process domain relevant information. However, Shanteau (1992) provides a broader approach in which the performance of experts is examined not merely within a domain but also on the task characteristics within that domain. Shanteau identifies five factors that directly contribute to competence in experts - domain knowledge, psychological traits, cognitive skills, decision strategies and task characteristics. While each of these factors will have varying levels of influence depending on the domain being considered it is possible to consider their particular application to expertise in map reading.

Firstly, domain knowledge possessed by skilled map readers is not just likely to be more extensive, it is likely to be organised differently. ‘Experts restructure, reorganise and refine their representations of knowledge and procedures for efficient application to their work-a-day environments’ (Durso & Dattel, 2006, p 57). Experienced map users might therefore be expected to extract added meaning from map symbols based on the known relationships of associated features or a familiarity with the environment being represented on the map (Montello & Freundschuh, 2005).

Secondly, Shanteau suggests experts display a pattern of psychological traits such as strong self-confidence, well-developed communication skills and an ability to adapt to new situations. While these traits are not pre-requisites for most tasks associated with map usage it could be argued that with the acquisition of expertise, a commensurate increase in confidence might be anticipated. Indeed experts in any field may well be outwardly displaying the confidence they have in their own abilities to perform well and to communicate effectively within their areas of expertise based on their own consistently superior performance.

The cognitive skills, which Shanteau identifies as the third essential for the achievement of competence in experts, include focused-attention abilities, an understanding of what is relevant and an ability to identify inconsistencies in familiar data. While these skills are necessary and indeed have been identified in experienced map users (Chang, Antes, & Lenzen, 1985) they may not be sufficient. Good spatial memory has been reported as advantageous in map reading (Coluccia & Louse, 2004), while mental rotation skills are predictive of performance in some map comprehension tasks (Cornell et al., 2003; Gunzelmann et al., 2004; Montello & Freundschuh, 2005). For the demanding tasks of navigating and self-location in unfamiliar environments, the ability to visualize the landscape represented on a map has been identified as a requirement for successful task achievement (Crampton, 1992; Eccles et al., 2006; Lobben, 2004). So, where experts differ from novices in many disciplines by their ability to process domain relevant information quickly and accurately, there are additional cognitive skills that can be shown to contribute to core expertise in complex map-reading tasks.

The fourth component of expertise that Shantau included in his theory is the use of decision-making strategies. These strategies are identified as assisting experts to overcome cognitive limitations and include the incorporation of dynamic feedback, simplifying complex situations to identify solutions and pre-planning strategies to meet difficult scenarios. Here Shanteau is addressing the cognitive processes that are explicit and employed during the gradual acquisition of expertise and the strategies that develop in response to the long-term influence of task characteristics. Map usage encompasses a wide variety of tasks. Each of these tasks may involve the use of different strategies and these strategies may differ between individuals engaged in similar tasks (Lobben, 2004). So, while 'everyone may use the same (cognitive) processes, not everyone uses the same strategies' (p272).

2.5.1 Map reading strategies

If map use is examined as an exercise in problem solving then the adoption of a suitable strategy to achieve the task will be viewed as essential from the outset. By their familiarity with the task, experienced map users will have developed a number of problem-solving procedures that assist in reaching the required solution. These strategies will vary across tasks. Self-location requires different strategies to those suitable for selecting a route or identifying a suitable site for urban development.

Similarly, strategy content and structure will be affected by individual preferences and operator experience with the task. A number of researchers have reported examples of strategies employed in map-related activities These include: the use of logically structured data comparison during problem solving analysis of GIS data (Audet & Abegg, 1996); gender specific strategies to enhance encoding and recall of route information (Lawton, 2001); generation of semantic representations from imperfect geographic information to improve decision making in urban planning (Bordogna, Chiesa, & Geneletti, 2006); vector integration and cognitive mapping to assist in search tasks (Gibson, 2001) and; chunking of route segments to aid comprehension in way-finding tasks (Klippel, Tappe, & Habel, 2003). Each of these strategies has been shown to enhance performance in the field in which they are employed and are therefore important in contributing to the overall understanding of expertise in map tasks. However, their relevance is highly task-specific. Shanteau suggests that expertise develops when actions initially learnt through explicit cognitive processes gradually evolve to more automated and implicit processing. Each of the various decision-making strategies might therefore contribute to the gradual development of superior cognitive functioning in experts, but by their heterogeneity provide only a partial picture of core expertise in map reading tasks.

So while map reading, in almost every case, requires inspection and interpretation of the symbols and associated data, how the visual search is conducted may be determined by the strategies selected. These strategies are in turn highly dependent on the task in hand. The important role of the task characteristics in the gradual acquisition and maintenance of expertise is now considered in the following section.

2.5.2 The nature of the task

Shanteau (1992) argues that practical demonstration of expert performance is highly dependent on the nature of the task. In domains where decision-making is based on information that is both reliable and frequently encountered then expert judgements are consistently more accurate than those made by less experienced decision makers. This view is strongly supported by the literature on chess Masters (Charness et al., 2005) and electronics engineers (Egan & Schwartz, 1979) already discussed. More recently, studies of radiologists diagnosing cancerous tissue (Hoffman, Shadbolt, Burton, & Klein, 1995), air traffic controllers monitoring aircraft movements in restricted airspace (Ackerman & Cianciolo, 2000) and expert engineering in software design (Sonnentag, 1998) provide evidence that where the task is familiar and based on predictable data, no matter how complex, then experts will provide more accurate judgements than novices. In domains where the tasks are less well structured and involve more dynamic scenarios perhaps also incorporating assessments of human behaviour, expert performance is less reliable (Kahneman, 1991). In the area of medical diagnosis, performance may be affected both positively and negatively with increased experience. Caulford and a team of researchers found that older physicians reached their decisions by a process of premature closure in which early impressions of a case biased any further analysis of later evidence (Caulford et al., 1994). Similarly, the use of pattern recognition by very experienced physicians, although efficient and reliable in some diagnoses, has been shown to increase the risk of failing to consider alternative conditions (Eva, 2002). Other domains in which expert performance has proved unreliable are those in which decision-making relies more on intuitive reasoning or judgemental heuristics and less on analytical processes such as legal professionals involved in rape cases (Krahe, Temken, & Bienbeck, 2007) the catastrophic consequences of child paediatricians providing false ‘expert’ evidence in cot death cases (Freeman, 2006) and inflexibility in problem solving by experienced tax practitioners due to rigid procedural information processing (Marchant, Robinson, & Anderson, 1991). Here experts have been found to under-use relevant and available information and depend too heavily on heuristic strategies.

So, in considering the effect of task characteristics in the domains where maps are central to the decision making process, it is necessary to evaluate to what extent information processed by map users involves either analytical or intuitive reasoning. Also, it will be equally important to consider how much the expertise is dependent on implicit cognitive processing and where task relevant heuristics are employed, how reliable they are in the problem solving process.

If it is considered that the majority of data presented on maps is highly accurate, reliable and presented in a static scenario, then any processing of that information should be reliant on analytical and explicit cognitive processes. In reality, however, the situation is more complex. Data presented on maps is not accurate in a veridical sense. Roads presented in the correct scale would be far too thin to be discernable so they are grossly exaggerated to aid easy recognition. They are also assigned an arbitrary colour to denote their size and usage. Likewise, specific features are represented by symbols which are neither accurate in form nor scale to the feature portrayed.

The reliability of the information presented on a map is equally affected by the conventions adopted by the original cartographic team and the relative importance attached to individual features and their locations at the outset. As a result, anomalies arise. In the Western world maps are predominately orientated North-up although the original meaning of ‘orientate’ was to align with the orient, i.e. align to the East (Harley & Woodward, 1987). Similarly, London residents of Kennington must journey in a Southerly direction to Vauxhall when using a street map. On the Underground map, however, Vauxhall is very clearly depicted to their North.

While the information presented on a map is generally static and unchanging, the map might well be employed to navigate through the environment at high speed. At such times the need to match the map representation with rapidly changing real world features may well require the use of accelerated information processing and the need to employ heuristic strategies. Maps are also frequently used in emergency scenarios when problem solving is time-limited and user familiarity with presented data will be required for the early identification of solutions from brief and ostensibly superficial map inspections.

So, while map data is generally in the form of static and reliable presentations, it can be seen that the task characteristics exert a powerful influence on how it is to be interpreted. Experienced map users gradually acquire an understanding that the representation of features may be highly accurate for one task but not for another. This, however, may engage implicit rather than explicit comprehension.

Likewise, the measured and deliberate inspection of a map at walking pace employs cognitive processes that are fundamentally different to those required for the rapid acquisition of key features during high speed navigation of an aircraft during a low level flight. Here the pilot will be employing well-rehearsed heuristic strategies to rapidly identify data corresponding to highly visible and essential features on the ground.

Shanteau’s proposition that domain expertise is most reliable when decision-making is based on predictable and accurately presented information in a static environment now becomes highly relevant. At first sight, accurate information in a static environment appears to describe accurately the processes employed in at least some map reading. However, it is now clear that depending on the task characteristics, presented information may not be entirely accurate; it may require considerable interpretation and information processing may be occurring in a highly dynamic scenario.

Accordingly, expertise reliability might reasonably be expected to decrease as the task characteristics of map use in some environments drive the type of cognitive processing in use away from the explicit and analytical end of the cognitive continuum towards the less dependable, intuitive and heuristic area of reasoning. This is an important consideration and one that is further addressed in later sections of this paper.

2.5.3 Summary of expertise in map-reading applications

Current theories of expertise which specifically address the improved information processing abilities of experts operating within their domains include Chunking theory, Template theory and Long Term Working Memory theory. While the majority of research incorporating these theories has been conducted in the domain of chess, Gobet (1998) has reported that three essential elements of chess expertise, namely selective search, memory for meaningful material and pattern recognition may be generalised to other domains. Indeed, three map-related studies (Chang et al., 1985; Gilhooly et al., 1988; Thorndyke & Stasz, 1980) have found evidence that participants employed chunking strategies and pattern-recognition techniques during map reading and memory tasks.

The role of deliberate practice in the acquisition of expertise has been reliably identified as the single most important element in domains beyond chess, such as music and bridge (Ericsson et al 1993). However, no studies directly report on the contribution of deliberate practice to map-reading expertise. This finding is surprising, particularly in view of the studies where participants were selected as experts based on arbitrary classifications such as type of degree or current employment. While it is unlikely that many map experts ever achieve the ten thousand hours of deliberate practice that is required for exceptional performance in domains like music and chess, it may well be that ten years experience of map-related tasks equates favourably with the observed minimum times for excellent performance in other disciplines. In the absence of any formal performance measures for map reading tasks, perhaps ten years experience with any map-related task being studied is a minimum threshold for which expert performance can be predicted. In any event the role of deliberate practice is clearly central to the achievement of map reading proficiency despite the apparent reluctance to address its importance in earlier literature.

Shanteau's (1993) theory of expert competence provides a broader perspective with which to study map users' skills. Across a number of professional disciplines, five factors emerge as contributors to the acquisition of expertise - domain knowledge, psychological traits, cognitive skills, decision strategies and task characteristics.

Each of these factors contributes to expertise but ultimately it is the nature of the task, which will determine the relevance and reliability of the expertise employed. The cognitive demands of a map task such as way-finding in upland terrain will activate certain decision strategies. These might include the use of contours to identify the route by reference to the surrounding hills. The availability and selection of the decision strategies is, in turn, a function of experience and domain knowledge. In deteriorating weather or in highly dynamic scenarios when feature information is impaired or degraded, the task may require different decision strategies. If suitable strategies are not available or those employed are inefficient then the level of expertise may deteriorate and become far less reliable.

Specialist cognitive skills such as good spatial memory or proficient mental rotation abilities and certain psychological traits, like professional confidence, may mediate the acquisition of expertise in map tasks. These will, however, be subordinate to the powerful influence of task characteristics.

Expertise in the use of maps, then, would appear to depend on the efficient employment of information-chunking techniques and the use of templates to process individual features as collective members of prototypical groups within familiar patterns or configurations. Truly expert performance occurs only after many hours of deliberate practice over prolonged periods. Even then it is highly dependent on the congruence between the nature of expertise possessed and the requirements of the specialist map task being performed.

2.6 Further Review of Literature within Experimental Reports

In each of the experiments described in the following chapters, literature relating directly to the research questions and the experimental design is reviewed within the experimental report.

Chapter 3: Evaluation of Skilled Performance in a Map Reading and Recall Task – Experiment 1.

3.1 Introduction

The research literature in Chapter 2 reviewed a number of theoretical approaches to the nature of expertise in map reading and comprehension. Although the five principal theories, Chunking, Template, LTWM, Deliberate Practice and Expert Competence differ in their accounts of how cognitive processes might contribute to the acquisition of expertise, all five theories share two core beliefs. Firstly, highly efficient information processing of domain relevant material is essential for expert performance. Secondly, acquired expertise is normally specific to one domain and on occasions may be further limited to specific tasks within that domain.

Studies designed to examine map-reading expertise must therefore attempt to both identify and quantify those cognitive skills which contribute directly to enhanced performance in the processing of information presented on a map. Areas where expert performance differs from that of novices may then be further inspected to provide a clearer insight into the cognitive processes which contribute to improved task achievement. However, given the heterogeneity of tasks for which maps are employed it is likely that there is a correspondingly wide diversity of task-specific cognitive strategies employed across the domain of map comprehension. Expert performance in one map-reading task will not necessarily predict exceptional competence in another.

In parallel it may be necessary to control for variations in general cognitive abilities, such as spatial memory or mental rotation ability, which may also assist in successful task completion but which may be independent of the information-processing skills directly contributing to expert performance.

The second section of this chapter addresses some of these considerations as they apply to the selection of an experimental design for a map-reading experiment. The third section of the chapter provides a detailed description of the first study conducted within this research programme to examine the information-processing strategies employed by experienced map readers in a map-reading and recall task.

The results of the study are presented in section four and further discussed in section five. The findings from the study are summarised in section six and the overall conclusions are outlined in section seven.

3.2 Research Design

This section presents the research questions. Literature relating to earlier studies of skill in map reading tasks is then briefly revisited and reviewed. Three studies are examined for their suitability to address the research questions together with their limitations. An experimental design for the current study, based on the Gilhooly et al. (1988) experiment, is ultimately selected and described. The section concludes with the justification for the choice of design.

3.2.1 The four research questions.

The first two research questions were posed in the original (1988) experiment and are again evaluated to confirm the earlier findings. The third and fourth research questions were not formally stated in the earlier study but are central to the research undertaken within this dissertation.

1. *Do experienced map readers have better recall for map information than less experienced map-users?*

2. *Do skilled contour map readers have a superior memory advantage for both contour and non-contour information?*

3. *Do experienced map readers employ cognitive strategies such as information chunking during encoding and recall of map information?*

4. *Do experienced map readers employ cognitive strategies such as templates to assist in the processing of spatial information presented on a map?*

3.2.2 Literature on research into map-reading expertise

The research into expert performance in map-reading tasks is neither extensive nor entirely convincing. Difficulties in matching participant experience with the experimental task characteristics have contributed to inconclusive results in some earlier studies.

Additionally, since a number of cognitive processes are employed during the encoding and recall of map data, isolating map-reading expertise from general cognitive abilities has also been problematic.

Nevertheless, three studies have suggested that map-reading expertise may be dependent on the successful development of task-related cognitive strategies and these studies are now considered.

3.2.2.1 Map-reading Skill

The review of earlier studies in chapter 2 has shown that expertise in map reading and comprehension is highly dependent on the efficient processing of visually presented information. In addition, the wide variety of tasks associated with topographic (terrain) map usage often requires a number of associated skills.

These include: efficient spatial memory performance; an ability to mentally rotate internal and external representations and; a familiarity with task-specific map presentations to facilitate the generation of 3D mental representations from 2D displays.

At a fundamental level, however, it is probable that experts process the visual information studied on a map both more efficiently and at a deeper level of comprehension than novices. Since capacity for spatial information in Short Term Memory is limited, it is again highly probable that, with experience, experts develop cognitive schemas such as ‘information chunking’ to facilitate rapid and efficient information processing of task relevant map symbols and data.

3.2.2.2 Information Chunking Strategies and Map Reading

Three studies have addressed the employment of ‘information chunking’ strategies in map reading tasks. In the first of these, Thorndyke & Stasz (1980) examined individual differences between three experts and five novices when studying a map in a recall task.

The authors had predicted firstly, that their expert subjects would employ specialised information processing strategies relating to map tasks and secondly; that they may employ similar operations to novices but due to their familiarity with the task they would perform them more efficiently.

The experts were observed to employ two distinct attentional procedures - partitioning (restricting study areas to sub-sets of map information) and dedicated sampling methods. Experts were further distinguished from novices by their adoption of different encoding strategies such as *relational encoding* (linking features by their spatial relationship) and *labelling* (to generate a verbal cue to assist recall). However, despite their different study patterns, the experts did not outperform the novices in their recall of information from the maps.

The results from this study suggested that familiarity with maps was not of itself predictive of good performance for the task of memorising and reproducing information from maps. Instead, Thorndyke & Stasz concluded that the employment of good learning strategies for the processing of spatial information and a good visual memory were more reliable predictors of accurate recall of map detail.

3.2.2.3 Expert Performance May Depend on the Experimental Task

Gilhooly et al. (1988) addressed the inconclusive results reported by Thorndyke & Stasz and suggested that map-reading expertise had not been demonstrated by all the experts in their study because planimetric (non-contour) maps had been used. By employing a larger sample size (38 experienced and 40 less-experienced map readers) and by including both planimetric and contour maps into their experimental design, Gilhooly et al. were able to demonstrate that experts' memory for map detail in the contour maps was superior to that of the novices. However this advantage was not observed for information recalled from the non-contour maps.

The authors further reported that the two groups of experts and novices did not differ significantly in the methods they employed to study the maps or in their use of non-specialist schemata. During recall, however, the experts employed more specialist schemas and paused less often than novices. Experts also recalled more of the non-specialist schema information than the less experienced group despite the equal use of 'lay' schemas by both groups during encoding.

These results supported the authors' contention that expert map readers employ a 'rich repertoire of schemata' (p107) to encode information from a map. Since the experts paused less often than novices during map study (measured by recording pauses longer than one second from the videotape record) it was suggested that this might have reflected processing of larger information packages during both encoding and retrieval. This pattern was consistent with the 'information chunking' mechanisms employed by experts in the studies of expertise within other domains discussed in chapter 2.

3.2.2.4 Contour Data Processing is Easier for Experts

In the third study of map reading and expertise, Chang, Lenzen & Antes (1985) examined the eye movements of a group of twenty-two experienced map readers with a similar number of novices engaged in a map-reading exercise. The authors found that although both groups did not differ significantly in the overall number of fixations, experienced map users had shorter fixations on contour related features during the encoding phase of the map study.

Chang and colleagues suggested that experts were processing contour information by integrating it into their evolving schemata and this facilitated a better understanding of the landscape being studied. Experts also performed better on their recall of absolute and relative heights. The authors attributed this superior performance to the experienced participants' ability to process larger chunks of information relating to contour information during the limited available study time.

Experts, the authors suggested, may have been more adept at transforming a two-dimensional representation in the form of a map into a three-dimensional mental image of the terrain depicted. However when presented with maps depicting irregular topographical information or random contour lines the experts' visual search times increased as they struggled to make meaningful patterns from atypical representations.

This result mirrored the additional cognitive processing required by chess Grandmasters when recalling random piece positioning and unstructured board layouts in the Chase & Simon (1973) literature.

.

3.2.2.5 Information Chunking and Template Theory

The studies above lend support to the concept that Chunking theory and its more comprehensive successor, Template theory, may provide highly credible accounts of how information is processed in a map-reading task.

Where the map corresponds to a known landscape or contains features familiar to the reader, experts might be expected to encode it not just as separate 'chunks', but within an overall template that incorporates the relationships between the groups of objects viewed (Davies, 2005; McGuinness, 1994). By the use of templates, experts may then employ three cognitive strategies to assist in the processing of topographic data. Firstly, experts may focus on the distinctive features of a display to establish how it may differ from the norm. Secondly they might identify what is familiar and typical and which therefore requires minimal processing. Finally they might employ spatial feature-matching of either the geometric or symbolic information provided on the map with geographic feature-matching in the landscape being represented (Chang et al., 1985). Any or all of these strategies may improve the efficiency and speed with which domain-relevant information is processed.

3.2.2.6 Summary of Considerations for Experimental Design Selection

Experiments attempting to establish which cognitive strategies are employed during map study and comprehension are therefore required to address several issues. Firstly, the task has to be sufficiently specialised to differentiate expert performance from that of novices. Secondly, the experts selected must be sufficiently familiar with the task to perform it at measurably higher levels of competence. Thirdly, the measures employed must be sensitive enough to capture possibly quite small differences between groups and fourthly the differences must be identifiably dependent on the altered cognitive functioning due to acquired expertise and not attributable to more general cognitive abilities.

Finally, and without doubt the most difficult task, is the need to incorporate into the experimental design a method of identifying which cognitive strategy is contributing to superior performance in experts.

Cognitive processes which contribute to expertise are both explicit and implicit. For this reason experts are seldom able to identify fully their thought processes as they operate within their fields of expertise. The elusive nature of expertise is that expert performance is not necessarily achieved through incorporating additional cognitive functions during information processing. Rather, through repeated practice, the number of iterative processes may be reduced as some become redundant or semi-automated. In this case the experimental objective might be to identify which cognitive processes are absent, or significantly reduced, as experts engage in the experimental task.

Through information chunking and the use of template schemas, experts may also be processing fewer items of map data to achieve the same or better levels of comprehension than novices of the overall landform portrayed. The experimental objective might then be to show that the number of map inspections required to achieve a given task reduces with increased experience in experts. However, reduced attentional activity in some areas of the map being studied may indicate either that the experts are processing the data more efficiently or that they simply are not attending to it. In this event results will always need careful interpretation.

Studies of expertise in map reading may need, therefore, to identify which map information does not appear to be processed by experts as well as that which is, in order to ascertain which cognitive strategies are being employed.

3.2.3 Characteristics of the research design

This section briefly describes the factors to be addressed by the experimental design in order to investigate the four research questions.

The first research question, '*Do experts have better recall for map information than novices?*' had not been satisfactorily demonstrated in the Thorndyke & Stasz experiment. Gilhooly et al., however, successfully demonstrated that experienced map readers do perform better if the maps are related to their experience. By researching and answering the second research question *'Do experienced contour map readers have superior memory for contour-related data?'* the authors identified the area of information processing where the expertise was most evident and showed that matching task to experience was critical to evaluating map-reading expertise.

Research questions 3 and 4, *'Do experienced map readers employ information chunking or the use of templates'* during processing of map information, were not answered in the Thorndyke & Stasz experiment. Some evidence of information chunking and possible use of templates was however identified in the study patterns and verbal protocols of participants in the Gilhooly et al. study.

It was considered that an experimental design similar to that employed by Gilhooly et al. therefore had considerable merit in addressing the first two research questions. With some modifications it might be improved to address the third and fourth questions with more conclusive results.

3.2.4 Selection of the experimental research design

This section provides support for the selection of an experimental design based on the earlier study of Gilhooly et al. and the rationale for introducing modifications to the original design.

3.2.4.1 The Gilhooly Experimental Design

The Gilhooly et al (1988) study successfully employed a between subjects experimental design in which a group of 38 skilled contour map readers was compared with 40 less-experienced participants reading, firstly, non-contour maps and, secondly, contour maps. After each five-minute map inspection the participants produced sketches of the remembered map data and answered questions related to the locations studied. Analysis of the information contained in the sketches and the accuracy of answers to the map questions provided clear evidence of superior memory performance for contour related information in the experienced participants. There were no group differences in memory performance for planimetric map data and non-topographical data from the contour maps.

In the second section of the experiment, 21 participants from the first experiment repeated the study and recall procedure using a different contour map and provided verbal protocols as they completed the task. The participants were instructed to point to the areas of the map they were studying and were filmed throughout the study and recall phases.

Results from the analysis of participant protocols revealed that the inexperienced map readers had higher instances of negative evaluations and reading place names and fewer instances of specialist schema use than the experienced map readers. Analysis of the filmed study patterns showed that experienced participants paused less often than novices suggesting the processing of larger information ‘chunks’.

3.2.4.2 Strengths of the Gilhooly Experimental Design

The main strength of the Gilhooly experimental design was to identify the importance of matching the experimental task with participant experience in any study of expertise. The results indicated that the authors had selected a contour map reading task which directly tested the skills possessed by their experienced participants.

By analysing the group differences for the amount of map information remembered in distinct categories, the authors further identified in which area of information processing the experienced map readers were gaining their advantage. More efficient encoding of contour data by the experienced group was shown to have contributed to their superior recall performance.

The study, therefore, successfully addressed the first two research questions by demonstrating that experienced map readers have superior recall for domain specific information. Analysis of participant protocols for specific memory encoding and recall techniques provided some evidence of the information processing strategies employed by each group.

3.2.4.3 Weaknesses of the Gilhooly Experimental Design

The experimental procedure required participants to study each of the planimetric and contour maps for five minutes before producing their sketches of the studied locations. By employing a single study period it might be argued that participants with good spatial memory or good sketching abilities would have an advantage irrespective of their map reading abilities.

Gilhooly et al. did not control for differences in spatial memory ability or sketching ability in their participants.

The authors chose a map of central Kentucky for their contour map task to ensure that the map area was unfamiliar to their participants. As first year geography students at Aberdeen University, it is likely that the experienced group would have had greater knowledge of UK map formats and symbols. An Ordnance Survey map might have provided a better match of experimental task to map reading experience.

In the second experiment, objective measures of participants attentional and retrieval procedures identified only one difference between the groups. The experienced participants had fewer pauses during recall of map data as measured by the percentage of time during which the position of the pencil did not change from one observation to the next. However, this measurement was obtained from studying and assessing the videos of participants engaged in the map sketching task and therefore may not have been sensitive enough to provide reliable evidence of information chunking as the authors suggested.

3.2.4.4 Proposed Modifications to the Gilhooly Design

The five-minute study time was sufficient to enable most participants to memorise the majority of data on the planimetric and contour maps. However, it was proposed that a single study interval with five separate one-minute study periods would provide a more dynamic examination of the encoding and recall procedures employed by participants.

Individual differences in spatial ability and sketching skill could be controlled for by administering the Paper Folding questionnaire (French, Ekstrom, & Price, 1963) and the Rey-Osterrieth Figure copying task (Meyers & Meyers, 1995) to all participants prior to the map tests.

Students at a British university would be expected to be more familiar with an Ordnance Survey map of a UK location rather than a topographic map of a North American state. Introduction of an excerpt of an OS map was proposed to provide a better match of task to experience.

By the use of a tracing tablet which accurately recorded pen strokes and pauses between pen strokes a more sensitive measure of information recall patterns could be achieved. From this data, evidence of information chunking might be more readily identifiable.

3.2.4.5 Summary

The Gilhooly et al. (1988) study employed a sound experimental design which successfully demonstrated that experienced and novice map readers did not differ in memory performance for non-contour maps. When using topographic maps, however, memory for contour data was shown to be dependent on experience.

The authors' measures for testing participants' recall by the use of a sketch map were effective and the employment of protocol analysis provided some useful insights into memory strategies adopted by the participants.

Improvements to the original Gilhooly design, involving the study procedure, contour map selection and controlling for spatial memory and abilities were therefore proposed. The requirement for a more sophisticated method of monitoring pen strokes during sketch map production using a tracing tablet was identified.

An experimental design based on the earlier Gilhooly study, but adopting the modifications proposed, was selected for the first experiment in the current study.

3.3 Method

3.3.1 Participants

Sixteen participants were recruited from the staff and students at the University of Sussex and were divided into two groups determined by their reported level of experience at reading contour maps.

Eight participants who were identified as experienced contour map readers formed the Skilled group. Two members of this group were lecturers with the Department of Informatics. The first was an experienced private pilot with a Service background and the second was practiced in the demanding sport of orienteering. Both had used contour maps extensively for a number of years. The remaining six members were students currently completing a BA in Landscaping Studies in the Centre of Continuing Education. During their course the students completed fieldwork which involved the constant use of contour maps. The average age of the Skilled participants was 47.5 (SD = 12.5) and three of the group were female.

The Novice group comprised eight post-graduate students in the Department of Informatics with some knowledge of contour maps. The group had a balanced distribution of females and males and a mean age of 30.1 (SD = 5.6). All participants were volunteers and were paid £10.

3.3.2 Apparatus and materials

3.3.2.1 Participant Consent Form.

A participant consent form was constructed and contained brief descriptions of the purpose of the study and the procedures to be employed in the experiment. The form outlined the voluntary nature of participation, the participants' right to withdraw and provided assurance of the confidentiality of any results. A signature from each participant confirmed their consent to participate. The consent form was produced as a requirement of the School of Science and Technology ethics committee. (See Appendix 2)

3.3.2.2 Familiarity with Maps Questionnaire

A 10-item questionnaire was purpose-designed to test participants' levels of competence with Ordnance Survey contour maps. Five of the questions were self-assessed measures of familiarity with map tasks and were measured on a three-point Likeart scale.

The five remaining questions required participants to identify the meaning of map symbols used on a Landranger map and to respond via the multiple-choice answers provided (See Appendix 3).

Participant scores were used to confirm the reliability of participant allocation into either the Skilled or Novice group.

3.3.2.3 The Educational Testing Service Paper Folding test

The Paper Folding test was a test of spatial visualisation ability from the battery of cognitive tests produced by the Educational Testing Service (French, Ekstrom & Price 1963). Each participant answered a set of 10 questions relating to folded pieces of paper, through which a set of holes had been punched. The participants then chose which of a set of unfolded papers with holes corresponded to the folded one they had originally seen.

The test was administered to control for differences between the groups in individual spatial visualisation ability. (See Appendix 4.1& 4.2)

3.3.2.4 The Rey-Osterrieth copying Task

The Rey-Osterrieth Complex Figure copying task (Meyers & Meyers 1995) is a recognized neuropsychological assessment of visual-spatial memory. Each participant was required to study an abstract figure (Figure 3.1) and reproduce it from memory in the form of a sketch. The test was administered to control for group differences in spatial memory abilities.

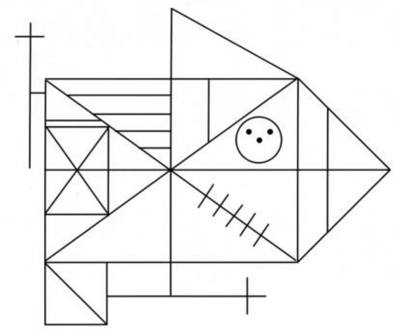


Figure 3.1 Rey-Osterrieth Complex Figure

3.3.2.5 Town Map

A non-contour map representing a fictitious town was utilised. The map was a facsimile of the Thorndyke & Stasz (1980 pp.141) town map employed for their original study but enlarged to measure 23 x 18cm. The town map (Figure 3.2) contained 33 separate features, 32 of which were named. The town map represented a prototypical layout of urban features for participants to memorise and to reproduce during the recall test. (See Appendix 5)

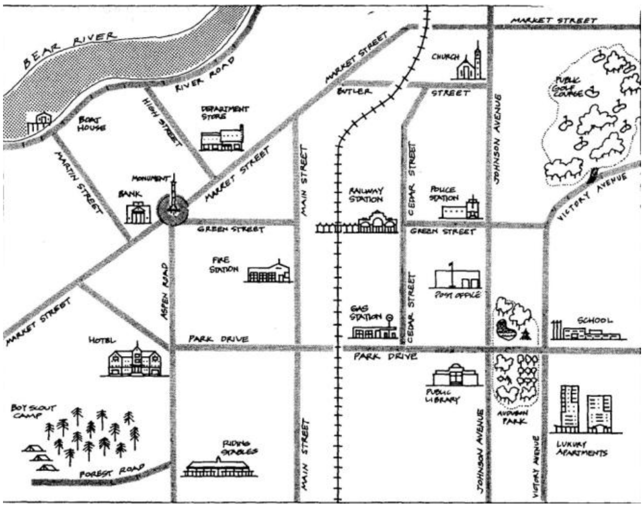


Figure 3.2 Town map

3.3.2.6 Town Map Questions

An 8-item questionnaire was produced with questions relating to detailed information in the town map. Participants were invited to select the correct answer from the two alternatives offered. Example questions were: '*On which avenue is the school? Victory or Johnson'*, and *'Is the Boat House at the end of High street or Martin street?*' Participants were instructed to circle their answer.

Beside each of their answers, participants were asked to provide a confidence rating on a 5-point Likeart scale ranging from *'not really sure (1)'* to *'supremely confident (5)'*

A correct answer scored +1 and an incorrect answer scored -1. The product of score and confidence weighting produced a greater numerical spread than the raw scores and was a more sensitive measure of memory performance (See Appendix 6). This marking design had been employed in the Gilhooly et al. (1988) study.

Responses to the town map questions provided a detailed measure of participant memory performance in the town map task.

3.3.2.7 Contour Map

The contour map (Figure 3.3) depicted an area approximately 3sq. miles around the Devon village of Yeoford. The area was selected from Ordnance Survey Explorer Series

Map (no.113), scale 1:25,000, and provided a similar density of information as the town map. There were 11 contour-related features and 29 non-contour features located in undulating terrain. The size matched the town map at 23 x 18 cms.

The purpose of the contour map was to test participants' memory for topographical and non-natural features presented within a topographical map. (See Appendix 7)

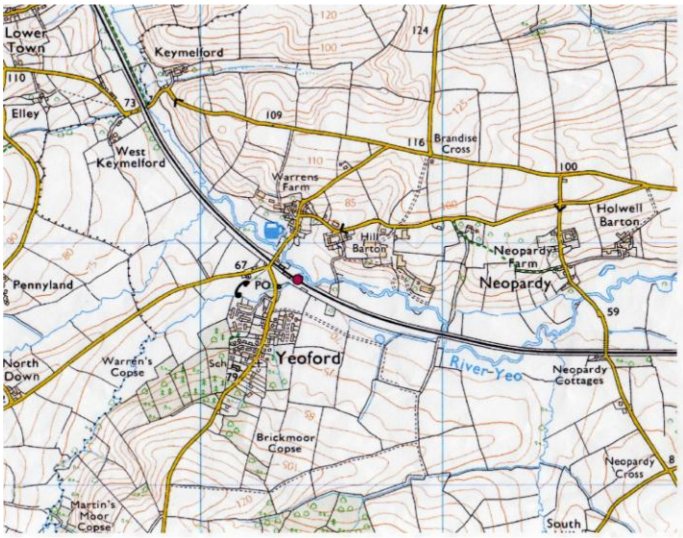


Figure 3.3 Contour map

3.3.2.8 Contour Map Questions

As with the town map an 8-item questionnaire was produced with questions relating to detailed information in the contour map. Participants were again instructed to select the correct answer from the two alternatives offered. Example questions were: *Is the road from Hill Barton to Warrens Farm steeper than the road from West Keymelford to Lower Town*? and *Is Yeoford at a greater elevation than Lower Town? Yes/no*. Participants were instructed to circle their answer.

Beside each of their answers, participants were once again asked to provide a confidence rating on a 5-point Likeart scale ranging from *'not really sure (1)*' to *'supremely confident (5)'* and confidence-weighted scores were again used for group comparisons (See Appendix 8).

Responses to the contour map questions provided a detailed measure of participant memory performance in the contour map task.

3.3.2.9 Electronic Graphics Tablet

The participants produced sketch maps during the recall phase and these were recorded using specially designed software, TRACE (Cheng & Rojas Anaya, 2004) operating with a Wacom Intuos 2™ graphics tablet. The tablet provided an effective working area of 30 x 22cms.

The participants sketched on to a paper resting on the graphics tablet. The electronically sensitive surface below the paper recorded the commencement and completion of every pen stroke together with the Cartesian co-ordinates during the compilation of the sketch map. Information from the graphics tablet was relayed to a monitor, resolution 1280 x 1024 pixels, beside the participant thereby displaying the content of the participant's map sketch during its production.

A detailed record of pen strokes was required to examine closely the nature of pauses between items of information recalled during the production of the sketch map.

3.3.2.10 Video and Audio Recording Equipment

Production of each participant's sketch map was recorded by filming the monitor adjacent to the graphics tablet using a Canon MV850i video camcorder. The camera ran continuously from the first inspection of the map until the participant stated they had finished their sketches. This provided a synchronous record of participants' verbal protocols in both the map study and recall phases.

3.3.2.11 Analysis of Verbal Protocols

Participants' verbal protocols were obtained and recorded using the 'think aloud' technique described by Ericsson & Simon (1993). The protocols were subsequently analysed using the HyperRESEARCH™ software programme. A total of 20 descriptions of cognitive processes or memory strategies were selected from studying the codes originally identified in the Gilhooly et al. and Thorndyke & Stasz studies and are listed below (Table 3.1). Instances of usage of each code were highlighted in each participant protocol during the map study and recall phases for both the town and contour map exercises.

Results from the protocol analysis provided the facility for individual and group comparisons of memory strategies.

Code	Definiton
Counting	Counting number of features
Feature Description	Identifying particular aspects of features
Inferring Height	Attributing values of altitude or rates of change of altitude.
Lay Schema use	Use of memory aids during encoding
Memory-directed sampling	Returning to specific map locations to identify partially remembered features or their relative locations
Metacognition	Analysis of personal performance on aspects of cognitive processing.
Negative evaluation	Critically evaluating performance or results
Partitioning	Dividing the map into sub units to facilitate the memory task
Pattern encoding	Using geometric or familiar shapes to identify spatial relationships
Positive evaluation	Evaluating personal performance positively
Random sampling	Unstructured identifying of features
Reading Heights	Merely reading as opposed to inferring heights
Reading Names	Reading names as a unitary task
Rehearsing names	Repeated reading of names
Relational encoding	Describing feature location as it relates to other features
Specialist schema	Employment of specialist knowledge to provide enhanced comprehension of the information studied or recalled
Stochastic Sampling	Search pattern partially determined by previous search and not entirely random
Systematic sampling	Directed searching for specific or classes of features
Task reference	Incorporating features of the designated task into the search and encoding processes
Verbal association	Use of word association as a memory aid

Table 3.1: Codes for procedures employed during encoding and recall of map data.

3.3.3 Procedure

3.3.3.1 Overview of Procedure

All participants were tested individually at a workstation sited in a conference room attached to the Representation and Cognition Laboratory, University of Sussex. The workstation contained the horizontal graphics tablet adjacent to a vertical monitor.

After completing the consent form, participants answered a short questionnaire to assess their experience with contour maps. They then engaged in two brief tests of spatial visualisation ability and spatial memory.

Participants then completed the town map task. The map was studied for one minute and removed. Participants recalled as much information as they could and reproduced it in the form of a sketch on the graphics tablet. A further four study periods were allowed to complete the task. On completion the participants answered questions relating to the information contained in their map sketches.

The sketch map was then replaced with a blank sheet of paper and a contour map was presented for study. For the contour map task the procedure was identical and was again followed by a set of questions.

On completion all participants were debriefed, thanked and paid £10 for participating.

3.3.3.2 Detailed Sequence of Testing

Individual participants were seated at the workstation throughout the one-hour experiment and completed the following tasks in the sequence outlined.

- **Participant consent form.** At the outset all participants were asked to read a brief description of the experiment, a statement about the voluntary nature of their attendance and to ask any questions if they wished. They then provided a signature to confirm their willingness to participate.

- **Familiarity with maps questionnaire.** Participants were presented with a ten-item multiple-choice questionnaire which they read and responded to by circling their chosen answers.

- **Paper Folding test.** Participants were presented with a second, 10-item, multiple-choice questionnaire. In each question a folded piece of paper containing a hole in one of the folds was displayed. Participants were required to select one of five alternative depictions of the paper after it was unfolded. The test was a measure of visual spatial ability.

- **Rey-Osterrieth Complex Figure copying task.** A copy of the Rey-Osterrieth figure measuring 18 x 15 cms was placed on the graphics tablet and participants were instructed to study it for one minute. The figure was then removed and participants were asked to recall as much detail of the figure they could remember in the form of a sketch. There was no time limit. This test measured visual constructive function and visual spatial memory whilst also introducing the participants to the use of the graphics tablet.

- **Town map task.** Prior to commencing the town map task participants were presented with written instructions which stated:

'You are about to begin studying a town map. The map will be made available for inspection for one minute, after which it will be removed and you will be asked to reproduce as much as you can remember in the form of a sketch. The map will be available for a further 4 inspections, again for one minute each, until all of the information has been recalled. The aim is to produce a sketch map of sufficient detail to provide a stranger with the information needed to locate facilities within the town. You are asked to 'think aloud' and provide a commentary on what you are attending to as you study the map and again when you copy the information onto your sketch map.'

When the participants were clear about the task, they began the first one-minute study period after which the map was removed and they began the production of their sketch map on the graphics tablet. If at any stage there were long silences they were encouraged to think aloud and to provide a commentary of their thought processes. When the participants had reproduced as much information as they could, the town map was then made available for a further one-minute study period and placed on top of their partially completed sketch. This procedure was repeated until five study periods and subsequent sketch activity had been completed.

- **Town map questions.** With their completed sketch maps still in front of them, participants completed a set of eight questions relating to information on their maps. The questions had alternative choice answers and included a confidence rating scaled from 1- *not at all sure* to 5- *supremely confident*.

- **Contour map task.** The procedure for the contour map task was a repeat of that employed for the Town map. At the outset the instructions presented to participants again described the procedure to be employed but now contained the following reference to the task:

> ***'The aim is to produce a sketch map with place names suitable for identifying the general layout of the area but which also includes information for walkers of differing fitness levels some of whom may wish to avoid very steep hills.'***

The participants then commenced the first session of a one-minute study period followed by the production of a sketch map on the graphics tablet. Once again this process continued until the five study periods and associated map sketching had been completed. Participants' verbal protocols were again recorded throughout.

- **Contour map questions.** With their completed sketch maps still in front of them, participants completed a set of eight questions now relating to information on their contour maps. The questions again had alternative choice answers and included a confidence rating scaled from 1- *not at all sure* to 5- s*upremely confident*.

On completion of all the tasks participants were given a short debrief and thanked for their participation.

3.3.4 Experimental design considerations

3.3.4.1 Experimental Constraints

Participants' availability dictated the duration of the experiment. It was felt that student recruitment would be more readily achieved for a time commitment of no more than one hour. This limited the map reading tasks to one planimetric and one contour map together with the associated questions.

The number of participants was primarily determined by difficulties in recruiting volunteers who were highly proficient contour map readers from the pool of students on the Landscape studies course. Five course members claimed to be skilled map readers. However after assessment using the Familiarity with maps questionnaire only four of these candidates were selected for the Skilled group. The Skilled group already had two lecturers from the Department of Informatics and was further supplemented with two PG students who were identified from their questionnaire answers to be experienced contour map readers. A larger sample size had been predicted from the numbers on the course.

3.3.4.2 Methodological Considerations

The experimental design incorporated similar procedures to those employed in the earlier studies for the map study and recall tasks including the use of participant protocols. Only minor modifications had been made to the original experimental testing.

However, introduction of the Wacom Intuos 2™ graphics tablet and TRACE purpose designed software, to record the participants' pen strokes constituted a novel approach.

Previous work by Cheng & Rojas-Anaya (2004) had tested participants using the graphics tablet to investigate the chunking of information during the copying of words and phrases. Using Graphical Protocol Analysis the authors had shown that the length of pauses prior to a pen stroke correlated with the amount of processing relating to the planned action. The processing time in turn correlated with the differences between low-level procedural components of a written phrase and the conceptual components. This procedure thereby provided a method of identifying the boundaries of chunked information. Pauses during the processing of intra-chunk information were shown to be reliably shorter than those observed between individual chunks.

The task of copying map information was recognized to be more complex than the reproduction of letters and phrases. Sketching a map requires the reproduction of script, for place names, in addition to the generation of geometric shapes or abstract designs for the map symbols. Nevertheless, it was anticipated that patterns of activity would emerge during the map sketching tasks. From these patterns, differences in information processing strategies between groups might be identified.

3.3.4.3 Data Analysis Procedures

To evaluate the differences between the two groups for a wide variety of measures, statistical analysis of 13 separate dependent variables was necessary. The use of t-tests or univariate analysis of variance procedures on every variable was therefore unsafe due to the risk of inflating the familywise error rate and increasing the chance of introducing type 1 errors (Field, 2000).

Instead the variables were inspected using a multivariate analysis of variance (MANOVA).

For this analysis four assumptions were made:

- Independence. All observations were statistically independent.

- Random sampling. Participants in each group were random samples of their populations.

- Multivariate normality. The dependent variables were considered to have multivariate normality within groups.
- Homogeneity of variance. The variance in each group was assumed to be equal.

The first two assumptions were addressed by the experimental design. The third assumption required normal distribution of data within the two groups. Inspection of the data for both groups for all tests indicated a significant value for the Kolmogorov-Smirnov test in four of the 26 sets of data. The normality of data was therefore violated in a small number of these comparisons.

However, when group sizes are balanced, as they were in this experiment, Field (2000) advises that multiple comparisons still perform well under small deviations from normal distributions. Howell (1997) confirms this view by claiming that ANOVA is a robust statistical procedure and normality assumptions in particular can be violated with relatively minor effects.

The Homogeneity of variance assumption was validated with a Levine's test. On two of the ANOVA tests the Levine statistic was significant indicating a violation of the assumption. Both tests were independently tested using a t-test with a more stringent analysis for groups with non-equal variance. Where appropriate the revised significance value was reported.

All other ANOVA reports in the results section give the significance and F values for the univariate analyses conducted following the initial MANOVA. All results given are for two-tailed tests except where stated.

3.3.5 Pilot study

A pilot study was conducted to assess the viability of the experimental design and the overall task timings.

3.3.5.1 Pilot Study Procedure

One skilled map reader and one inexperienced map user were tested using the two psychological tests, the town map, a contour map of Amberley and the associated questionnaires.

Both participants completed the town map task without difficulty and scored above 50% for the questions. In the contour map task the experienced map reader produced a workable sketch and provided six out of eight correct answers to the set of contour questions. This participant did however state that she had visited the location recently. The inexperienced map reader had some difficulty with the contour related questions due to inaccurate and incomplete contour data on the sketch map and scored three out of eight.

Participants' visual and audio recordings and graphic tablet pen-stroke data were checked. Audio levels were found to be very low during both of the recordings and some trace data was corrupt.

3.3.5.2 Changes Resulting from the Pilot Study

As the contour map location had been familiar to the experienced participant this highlighted the need to select a location even further removed from the local area. After a detailed search for alternatives, two locations in Devon were identified. Yeoford was finally selected for the balance it provided between contour and non-contour features. An associated set of questions was produced.

The low audio levels were addressed by replacing the camcorder microphone with a more sensitive model.

The incomplete data from the graphic tablet had resulted from an incompatibility between the designated work area on the tablet and the area defined by the software during alignment. The problem was resolved by altering the alignment procedure and re-aligning before each map exercise.

The revised procedures were tested with a non experienced participant to ensure that the problems identified in the pilot study had been addressed.

3.4 Results

3.4.1 Familiarity with maps questionnaire, Paper Folding and Rey Figure copying tasks

To assess their map reading competency participants completed a ten-item Familiarity with maps questionnaire. Out of a possible maximum of 20 the Skilled group scores (M = 14.4, SD = 1.5) were higher than the Novices (M = 9.5. SD = 2.7). Inspection by univariate analysis ANOVA showed this was significant, $F(1, 14) = 19.6$, $p = .001$.

To provide measures of general spatial ability and spatial memory performance, participants had completed the Paper Folding test and the Rey-Osterrieth Complex Figure copying tasks.

For the Paper Folding task the Skilled group scores (M = 5.9, SD = 2.0) closely matched those of the Novices (M = 6.1, SD = 1.5), F = .084, p = .78 ns. In the Rey-Osterrieth Complex Figure copying task the Skilled group scores (M =25.8, SD =3.4) were similar to those of the less experienced group (M =24.4, SD =5.3), F(1,14) = .4, p = .55 ns.

Assessment of participant scores and comparison of group means showed that Skilled and Novice group performances differed in their levels of experience with maps but were not dissimilar in both of the measurements of spatial ability.

3.4.2 Town map task

The town map task related to the first research question: *Do experienced map readers have better recall for map information than less experienced map users?*

Experimental instruments: Participants' sketch maps and town map questions

Participants' completed sketch maps were examined and assessed for the content and accuracy of information present. Each feature named and accurately located attracted a full mark while inaccurate feature positioning or unnamed features scored only a half mark. The maximum possible score was 33.

Comparison of the Skilled group scores (M =28.3 SD = 3.8) showed that they had performed marginally better than the Novices (M = 24.6, SD =3.4) but did not differ significantly F(1, 14) = 3.97, p = .07.

The accuracy of the information contained within participants' map sketches was examined by an oral test of eight alternative-choice questions. Participants were also asked to rate their confidence in the accuracy of their answers on a five-point scale. Correct answers were scored at plus one while incorrect answers were scored at minus one thereby providing a theoretical maximum score of +40.

The Skilled group confidence-weighted score of (M = 20.6 SD = 11.5) for the town map questions did not differ significantly from that of the Novices (M =14.5 SD = 8.0), F(1, 14) = 1.53, p = .24.

The Skilled group did not record more information in their sketches of the town map than the Novice group. Nor did they interpret their map information more accurately when questioned. For the town map task the Skilled group therefore did not appear to have any advantage over the less experienced group.

3.4.3 Contour map task

The contour map task addressed the second research question: *Do skilled contour map readers have a superior memory advantage for both contour and non-contour information?*

Experimental instruments: Participants sketch maps and contour map questions

Participants' sketches of the contour map were again marked for accuracy and completeness. Individual features were scored with one if correctly located relative to adjacent features but only .5 if included but incorrectly positioned or incorrectly named. Contour-related information was similarly assessed. However, since the topographic features were unnamed they were awarded one full mark if they were correctly positioned. Contour data had been presented in the form of contour lines or written descriptions such as 'steep hill'. Both formats were accepted as correct. The maximum score for contour and non-contour data was 40.

The Skilled group (M = 28.0 SD = 4.0) included significantly more information on their map sketches than the Novice group (M =22.0 SD2.4), $F(1,14) = 13.3$ $p<.01$. However when the map detail was sub-divided into feature-related and contour-related information the Skilled group performance was superior only in the amount of contour-related information reproduced on their sketch maps (Table 3.2).

Information type	**Group Means (SD)**		**Sig**
	Skilled	Novice	
Feature-related	19.5 (4.2)	16.3 (2.6)	ns
Contour-related	9.0 (3.0)	6.0 (2.1)	*
Combined	28.0 (4.0)	22.0 (2.4)	**

**Significant at .01 level *Significant at .05 level

Table 3.2 Group means (SDs) for features recorded in contour sketches

Participants were again tested on the accuracy of information on their maps by answering eight questions and providing confidence judgments with each answer. It had been predicted that the Skilled group would have reproduced a more comprehensive sketch and acquired a better comprehension for the map location than the Novices resulting in superior performance in this task. In the event both groups did poorly. From a possible maximum of 40, Skilled group scores for confidence-weighted answers (M = 8.9 SD = 5.5) were marginally but not significantly better than Novices (M = 6.3 SD = 5.4), $F(1,14) = .93$, $p = .35$).

Summary The second research question was therefore partially answered. The experienced group did record more information on their sketch maps in this task and as anticipated the superior performance had been achieved on contour rather than non-contour features. However, in the task of interpreting their map information for the questionnaires, both groups produced equally poor results.

3.4.4 Graphical Analysis

Analysis of the Graphical data collated during the production of participants' sketch maps was conducted to address the third research question: *Do experienced map readers employ cognitive strategies such as information chunking during encoding and recall of map information?*

Experimental instrument: Graphical Analysis of participants sketch map data

The Graphical Protocol data provided detailed values of the elapsed time between the commencement and completion of each pen stroke and a record of the time between the completion of each pen stroke and the commencement of the next.

It had been hypothesised that the more experienced map readers might engage in more efficient processing of information during the encoding and retrieval of map data and this could be achieved by information chunking. In this event experienced map readers might be expected to encode more information in each chunk. This would be evident by the Skilled group demonstrating fewer long, or inter-chunk, pauses than the less experienced group. However, the variability in data being transferred on to participants' sketches and individual performance variations might be expected to introduce considerable inconsistency in chunk sizes and durations. Predicting a definitive pause value for the commencement of an inter-chunk boundary was therefore difficult. An arbitrary value of one second or above had been employed in the Gilhooly study but had not been precisely predicted or accurately measured. Nevertheless this value was initially adopted for the data analysis.

Detailed inspection of the Graphical Analysis data was therefore conducted by setting thresholds for pause values in 11 increments between .05 and 20 seconds to identify the frequency distribution of each pause length. Histograms were generated for each of the following pause values, .05, .1, .25, .5, .75, 1.0, 2.0, 3.0, 4.0, 5.0, 10, and 20 seconds.

The histograms revealed large individual differences between the members of each group but no reliable between-group differences when the individual results were averaged and compared.

This result was surprising since the Skilled group had transposed more information on to their contour maps than the Novices within similar time frames, thereby indicating that more information had been remembered by the Skilled group without providing an explanation of how this might have been achieved.

Yet while the Skilled group did not appear to reproduce the sketched data with measurably fewer pauses, examination of the pen-movement distance data revealed group differences in the method of map production. The percentage of data added to the maps at a greater distance than 500 pixels (approximately 15 cms.) or more from the previous pen stroke was significantly higher for the Skilled group ($M = 7.9$, $SD = 2.9$) compared to the less experienced group ($M = 4.0$, $SD = 2.5$), $F(1,14) = 8.05$, $p < .01$.

One interpretation of this result might be that the Skilled participants were grouping features that were related spatially or semantically and not merely proximally.

Summary Evidence of information chunking was not identified in the pause data analysed. However the move distance data indicated patterns of activity for which the employment of information chunking by the experienced group was one possible explanation.

3.4.5 Protocol Analysis

Analysis of the participants' verbal protocols was conducted to investigate the fourth research question: *Do experienced map readers employ cognitive strategies such as templates to assist in the processing of spatial information presented on a map?*

Experimental instrument: Analysis of participants' verbal protocols

The video and audio recordings for each participant were examined to identify instances when participants employed strategies relating to the 20 procedural codes (defined in section 3.3.2.11) during map study and recall. These were identified and entered into the database. Group scores for use of the main codes in the town map exercise are provided in Table 3.3.

In the town map exercise participants from both groups frequently employed the aide-memoire of *reading names aloud* when encoding and recalling information. While the Skilled group recorded a lower mean number of instances (M = 42, SD = 3.46) compared to the less experienced group (M = 50.6, SD = 10.6), these differences were not significant.

Similarly the use of *relational encoding* in the town map task was employed by both groups with almost equal frequency. The Skilled group (M = 20, SD = 11.2) recorded more instances than the Novices (M = 18.6, SD = 13.3) but again these differences were not significant.

For the remaining codes in the town map task, there was some evidence of the use of the procedural codes of *metacognition* and *lay schema use* in some participants' protocols but no group differences were evident for these or the remaining codes.

Town Map			
Procedural Code	**Group means (SD)**		
	Skilled	**Novice**	**Sig**
Reading Names	42.0(3.5)	50.7(10.7)	ns
Relational Encoding	20.0(11.2)	18.7(13.3)	ns
Lay Schema	10.0(11.3)	5.0(5.3)	ns
Metacognition	8.0(2.6)	7.7(8.9)	ns

**Significant at .01 level *Significant at .05 level

Table 3.3 Group mean scores (SDs) for procedural code usage in the town map task

It was noted, however, that for both the *lay schema* and *metacognition* codes, the individual scores across members of the group were not equally distributed leading to large standard deviations. Group comparisons, therefore, were not considered reliable for these codes as they reflected large individual differences within each group.

However, with the examination of the verbal protocols for the contour map a different picture emerged. When the Skilled group encoded and recalled the contour data, the participants employed the *relational encoding* strategy more than twice as often (M = 21.8 SD = 10.1) as the less experienced group (M = 9.7 SD = 4.6) and this difference was significant $F (1, 14) = 9.43$, $p < .008$. An example of *relational encoding* was '*The railway runs along the valley*'

Similarly, examples of *inferring height* occurred in the protocols of the Skilled group almost twice as often (M = 27.6 SD = 8.4) as in those of the less experienced group (M = 14.5 SD = 4.5). Again the group differences were significant $F (1, 14) = 15.07$, $p < .002$. An example of *inferring height* was *'Lower town is actually higher than Yeoford'*

The Skilled group appeared to differ in one further encoding and retrieval strategy by their use of *specialist schemas*. This verbal protocol code had been defined as 'employing specialist knowledge to provide enhanced comprehension of the information being studied'. Examples included '*we have a spur running down between these two areas of high ground*' and '*there are a couple of re-entrants (small valley at the head of a stream) from the East*'. The Skilled group averaged nearly 5 examples of *specialist schema* use per participant (M = 4.75 SD = 5.4) while in the Novice group only two participants employed specialist knowledge and then only on a total of three occasions (M = .375 SD =.74). Accordingly the groups differed significantly, $F(1,14) = 5.0$, $p < .043$. These results are presented in table 3.4.

Of interest here were the large individual differences as illustrated by the associated high values of standard deviation within group scores for this procedural code. These reflected a large variance in specialist knowledge within the experienced group and highlighted the difficulties in consistently capturing the complex nature of specialist knowledge within a protocol analysis dialogue alone. The Levines test for the equality of variances confirmed this disparity and showed that the group variances differed significantly. Accordingly a further t-test was applied in which the equality of variances was not assumed. With this more rigorous test a revised significance value was obtained, $t(7.3) = 2.24$, $p = .059$ for a two tailed test and indicated that the earlier result was unreliable.

Contour Map			
Procedural Code	**Group Means (SD)**		**Sig**
	Skilled	**Novice**	
Reading Names	21.2(9.2)	23.4(8.0)	-
Relational Encoding	21.8(10.1)	9.7(4.6)	**
Inferring Height	27.6(8.4)	14.5(4.5)	**
Metacognition	5.9(2.3)	4.0(2.0)	-
Lay Schema	2.7(1.6)	2.2(1.6)	-
Specialist Schema	4.8(5.4)	.38(.74)	*
Task Reference	2.6(2.8)	1.37(.92)	-
Negative evaluation	2.7(2.8)	1.1(1.5)	-
Positive Evaluation	1.5(1.4)	.13(.35)	-
Partitioning	.76(1.75)	.13(.35)	-
Pattern Encoding	.13(.35)	.25(.46)	-

**significant at .01 level   *Significant at .05 level

Table 3.4 Group mean scores for procedural code usage in the contour map task

Although all statistical testing within this research had employed the two-tail test statistic, evaluating whether specialist map readers use specialist schemas could be considered a unidirectional test. Accordingly the one tail test statistic was considered appropriate and the result was significant at $p = .029$.

The remaining codes occurred infrequently and only in some of the participants' verbal protocols. Accordingly the cumulative scores were too low to provide reliable statistical evidence of group differences.

The low occurrence of the memory strategies of *partitioning* and *pattern encoding* had been anticipated since the incorporation of a one-minute study period into the experimental design had provided a more continuous cycle of information encoding and recall. Where Thorndyke & Stasz had employed a two-minute study time and Gilhooly et al. a single period of five minutes the task characteristics of these earlier experiments were more suited to a test of spatial and verbal memory rather than an examination of the nature of information processing strategies employed in map reading. Within the modified experimental design of Experiment 1, while scores for *specialist schema* use had closely matched those observed in the earlier studies, mean scores for *reading names*, *inferring height* and *relational encoding* were all above 20 for the Skilled group. This differed from the participants in the Gilhooly study who scored no more than three for each of these categories. These later results suggested that the process of encoding and recalling map information had been more reliably represented in a continuous cycle of map inspection and sketching and the results from the verbal protocols in the earlier experiments may not have accurately captured the complexity of the cognitive processes employed.

Summary The groups did not differ in the frequency of use of the designated protocol codes in the town map exercise. When participants encoded and recalled information in the contour map task however, group differences emerged. The Skilled group employed the procedures of *relational encoding*, *inferring height* and *use of specialist schemas* significantly more frequently than the less experienced group. The increased use of these codes by the Skilled group might have reflected the grouping of features during the processing of map information within a framework of specialist knowledge or templates.

3.5 Discussion

3.5.1 Characteristics of the participants

The experimental design incorporated group comparisons between experienced and non-experienced map readers. If conclusive results were to be achieved there was therefore a requirement to establish a clear demarcation between group skill levels at the outset. In concert with reports in some of the previous literature on expertise in map reading, this was not a straightforward task. For this experiment, skilled map readers had been sought from the Landscaping studies course where the use of contour maps was a prerequisite, but not all the candidates were as skilled as they had reported. Similarly among the ‘capable’ map readers in the Novice group, two achieved results in the map questionnaires above those of several of the experienced group. The criteria for group selection had initially been based on participant self-reports of contour map usage and skill levels but was subsequently modified by participant scores for the Familiarity with maps questionnaires as described below.

3.5.1.1 Participants Map-reading Experience

Of the five skilled map readers from the landscaping course, four had scores above 70% for the Familiarity with maps questionnaire. The two staff members at the Department of Informatics who had been recruited as skilled map-readers also had similar scores. In addition, two of the post-graduate students who had been selected as having some knowledge of maps also scored above 70%. The decision was taken, therefore, to include all eight of the participants who scored higher than 70% in the Skilled group at the outset of the experiment.

Within the group of eight Novices the map questionnaire scores were all below 60% except for the reclassified candidate from the landscape course who had scored 62%.

The definition of skilled or novice map-readers had thus been originally determined by self-report measures but was subsequently refined by the results of the questionnaire. It was, however, recognized that scores on one questionnaire lacked the sensitivity to capture the full complexity of skills employed by an experienced map reader and that the participants’ performances might be expected to vary considerably within each group depending on the nature of the task. Evidence of large individual differences in some of the experimental measures emerged during the Graphical Analysis and the difficulty in accurately defining skill levels at the outset may have contributed to this finding.

3.5.1.2 Participants Spatial Skills

The two tests of spatial skills confirmed that although the groups had different levels of knowledge for contour maps they were of similar spatial abilities. This was important since the main experimental measures were designed to examine whether information processing strategies between groups differed depending on experience levels independently from spatial abilities.

3.5.2 Discussion of the first research question

Research Question 1: *Do experienced map readers have better recall for map information than less experienced map users?*

Experimental instrument: Town map sketch and town map questions

Results from the town map copying task and the town map questions showed that the groups did not differ in the amount of information they copied and remembered from their planimetric maps. This confirmed the earlier Gilhooly et al findings that experienced map readers did not have superior memory for information from all maps. Moreover it supported the central tenet of expertise theories which states that expert performance is dependent on the characteristics of the task. Where the Skilled map readers were faced with a map task which did not draw on their specialist knowledge they performed no better than the Novices.

3.5.3 Discussion of the second research question

Research Question 2: *Do skilled contour map readers have a superior memory advantage for both contour and non-contour information?*

Experimental instrument: Contour map sketch and contour map questions.

The results from the contour map task clearly indicated that the Skilled group had outperformed the Novices in the amount of information transferred to their maps in confirmation of the second research question. Specifically the discovery that the advantage for the experienced group lay with the amount of detailed *contour* information transferred rather than the *feature-related* information was further confirmation that the nature of the task had tapped into the specialist knowledge employed by the Skilled group. It was highly probable that familiarity with the topographical representations had facilitated the information processing of this data by the experienced participants. Again these two findings replicated those of the Gilhooly et al. study despite the introduction of a UK rather than a North American topographical map for this study.

However, the results for the contour map questions were unexpected. It had been anticipated that the Skilled group would demonstrate superior performance in interpreting from the information in their sketch maps details about the terrain. Both groups scored less than 25% with no significant differences between the groups. The most likely reason for this result was that the questions had been too demanding leading to floor effects.

The questions had been similar in format to those used in the pilot study. However, the location had been changed, and so too had the questions. While the very experienced map reader had scored over 75% on the original pilot study questions this may have been due to a higher level of map reading skill than that held by the Skilled group or her familiarity with the location. It may also have been due to subtle differences in the subsequently revised questions which increased the difficulty of the task.

Conclusion As predicted, the Skilled group outperformed the Novice group in their recall of contour information, but not features. The groups did not differ in their test questions possibly due to floor effects.

3.5.4 Discussion of the third research question

Research Question 3: *Do experienced map readers employ cognitive strategies such as information chunking during encoding and recall of map information?*

Experimental instrument: Graphical Analysis of participants' sketch maps

The Graphical Analysis data had provided a very detailed record of participants' pen strokes during the production of their maps. It had been anticipated that group differences in encoding and recall patterns would be identified within the data. Further it had been hoped that the Skilled group would employ fewer long (inter-chunk) pauses and thereby verify that within each chunk they were encoding more items of information than the Novices. Despite very thorough inspection of the data it had not been possible to isolate any reliable differences in the distribution of pause intervals between the groups. Four possible explanations for this result are now considered.

Firstly, there may have been no between-group differences in the frequency of information chunking activity during the encoding and recall phases. While this was possible, it would not explain how the Skilled group had processed more information, particularly contour data, than the Novices within similar time frames. Since the groups had not differed in their spatial ability or spatial memories their advantage had to lie within the strategies they employed for processing the contour data.

Secondly, the histograms displaying each of the 11 pause intervals against frequency of occurrence showed a distribution in which the short duration pauses (.05/.1/.25 & .5 seconds) were highly populated but with large variations between the participants. Group comparisons merely smoothed out the individual variation to produce highly similar results for each of the incremental pause values across the groups. It is likely that the large individual variation in the patterns of participants' pauses during the sketching task had the effect of blurring the inter-chunk and intra-chunk boundaries when group results were integrated. This may have directly contributed to the masking of any group differences.

The third explanation regards the levels of experience of the participants. The effect sizes for all the experimental measurements in the contour map task had not been large. Allocation of participants into either the Skilled or Novice group had not been based on the strict criteria employed to distinguish experts from non-experts. It is possible therefore that the group differences in information processing strategies would have been achieved with only minor differences in such techniques as information chunking. The effect size might simply have been too small to measure within this experimental design.

The fourth reason for failing to identify information chunking in the Graphical Analysis is also considered the most likely. Previous work with the Graphical Analysis equipment had tested participants with tasks or elements of tasks such as producing letters, words, short phrases or numbers. The length of both inter-chunk and intra-chunk pauses had varied dependent on the task as well as for each participant. In this study during the reproduction of the contour map sketch, participants had annotated names, symbols, contour lines and occasionally numbers. While the quantity of data recorded may have been similar, the representations were not consistent across participants. For instance, where some participants had constructed comprehensive patterns of contour lines others had simply recorded spot heights. As a result the graphical data was recording a range of inter-chunk pause times associated with a number of different information reproduction tasks. The variability in pause times across all the sketching tasks might well have been sufficiently large to eclipse the subtle differences between groups for any of the separate tasks.

Finally, although the analysis had failed to detect direct evidence of chunking in the pause data there had been an interesting finding in the move-distance data. It was shown that the experienced participants had made significantly more additions to their maps at a distance greater than 500 pixels (15cms) from the previous pen stroke. If this was evidence that the Skilled group had encoded and recalled features which were linked by spatial or semantic relations and not just proximally located then these features may have been chunked into sets of associated features. This interpretation was consistent with the results from the Protocol analysis which suggested that the Skilled group were employing schemas and integrating features into groups more often than the Novices. As evidence of the possible employment of template schemas by the experienced group, these findings are further addressed in the following section.

Conclusion: Inspection of the Graphical Analysis data failed to identify any group differences in the amount of information chunking activity undertaken during the processing of map data. Four possible reasons were considered: firstly, there may have been no between-group differences although this was unlikely given the superior performance of the Skilled group’s recall of information; secondly, the large individual differences may have blurred any clear group distinctions; thirdly, the map-reading ability of each group might have been only marginally different and information processing differences too small to measure by graphical analysis and; fourthly and most likely, the diversity of tasks in reproducing contour map data introduced a range of differing information chunking boundaries associated with each task. When examined together, pauses defining inter-chunk boundaries for individual tasks thus merged with adjacent pause values precluding meaningful group comparisons.

3.5.5 Discussion of the fourth research question

Research Question 4: *Do experienced map readers employ cognitive strategies such as templates to assist in the processing of spatial information presented on a map?*

Experimental instrument: Analysis of participants' verbal protocols

Examination of the verbal protocols provided some insights into the differences in information processing between each group. While both groups had employed the technique of *relational encoding* (Describing feature location as it relates to other features) in the town map task, when the contour map was studied only the Skilled group recorded similar levels of usage of this technique. In the Novice group instances of *relational encoding* fell to half those recorded in the planimetric map exercise. However it was not clear from the verbal accounts whether or not the Novices had been affected by the unfamiliarity of the information they were processing or if the extra cognitive processing employed to interpret the map data resulted in a failure to adopt a strategy that had served them well in the earlier task.

The Skilled group also employed procedures in which they were identified as *interpreting height* and *employing specialist schemas* significantly more often than the Novices. This result suggested that their greater familiarity with contour data, demonstrated by their sketch map scores, may have enabled the experienced group to integrate contour information with feature information to produce more complex propositional representations of the terrain. The integration of features into familiar patterns of associated objects during encoding and recall of complex information is a central premise of Template theory.

Additionally, the Skilled group may have been constructing a detailed 3D mental image of the area portrayed on their maps. By navigating around their mental images these participants would have had access to information gleaned from their height analysis which then provided another dimension in which to employ *relational encoding*. This was evidenced in the verbal protocol statements which included descriptive elements of features imagined within their topographical context e.g. *'Lower*

Town is actually higher than Yeoford'. Use of this extra dimension may therefore have contributed to higher scores both for *inferring height* and *relational encoding* by the more experienced group due to their construction of a mental image somewhat richer in detail than the less experienced participants.

This view was further supported by the Graphical Analysis, which indicated that the Skilled group were progressively encoding and recalling some features more widely dispersed than those recalled by the novices. One explanation for this might have been that the experienced group had been encoding individual features not simply proximally related but also according to their topographical, semantic or spatial relationships with other features. Similarly, the less experienced group might have had a greater tendency to encode features only in close proximity to one another and from more narrowly defined locations. In both of these accounts the Skilled group would appear to have been interpreting the contour map data within a broader framework and with a better comprehension of the relationships between features than the Novices. This would be entirely consistent with the experienced participants' use of prototypical configurations or templates to encode and recall groups of features during the information processing of geographical data.

However, one confounding variable may have been inadvertently introduced by the inclusion of three students in the Novice group for whom English was not their first language. As the difficulty of the task increased these individuals may have suffered disproportionately from the increased cognitive resources required to articulate their thoughts in English.

Finally, the low occurrence of protocol codes relating to *random sampling* and *memory directed sampling* was attributed to the revised experimental design. Previous studies had employed longer study periods and a single recall procedure which had placed possibly too much emphasis on participants' memory for the map data. To examine closely the cognitive strategies employed by the more experienced map readers this study had deliberately altered the focus onto the information processing activity during a continuous cycle of encoding and recall.

Conclusion: Information processing by the Skilled group during the contour map task had included more examples of *relational encoding, inferring height* and *specialist schema use*. Additionally, the move distance data had shown that the Skilled participants may have more regularly encoded and recalled features related in contexts other than close proximity. Taken together these findings gave strong support to the contention that the Skilled participants had employed cognitive schemas, or templates to assist in the information processing of contour map data to achieve superior performance in the reproduction of information on their sketch maps.

3.6 Summary of Findings

The results replicated those of the Gilhooly et al. (1988) study in three important areas. The Skilled group did not differ from the Novice group in the information recalled for the non-contour map exercise, nor did they differ for feature related information in the contour map task. However, by recalling more contour data, the Skilled group outperformed the Novices in the content of information reproduced on their contour maps. Surprisingly, the superior performance of the more experienced group did not extend to the contour map questions. On this task both groups performed equally poorly, possibly due to floor effects.

In contrast to the Gilhooly study, however, the experimental design employed here incorporated an almost continuous cycle of encoding and recall of data. In addition, group differences in spatial ability and memory were controlled for. As a result, any differences in information recall were more likely to be dependent on the cognitive strategies employed by each group during information processing.

It had been anticipated that the Skilled group might have employed information chunking as a cognitive strategy. Examination of the Graphical Analysis data had provided a detailed record of the pause intervals between pen strokes during sketching activity. Evidence of fewer information chunks, defined by fewer inter-chunk pauses, would have confirmed the use of information chunking. However, it had not been possible to identify the temporal chunk boundaries with sufficient accuracy to confirm that information chunking had contributed to the better recall of contour data by the Skilled group. Four possibilities for this inconclusive finding were considered. Firstly, the groups may not have differed in their use of information chunking; secondly the considerable variation in individual temporal chunk signals may have masked any group differences; thirdly the disparity between the groups' map reading experience may have been too slight to generate an experimental effect measurable by the Graphical Analysis and; finally and most likely, the heterogeneity of tasks employed to reproduce data on to a contour map may have resulted in an overlapping of inter-chunk boundaries for the individual tasks and thereby precluded valid group comparisons for information processing differences across the entire map sketch. As a result evidence of information chunking activity was not reliably identified.

It had also been predicted that the second cognitive strategy the experienced group might employ was the use of cognitive schemas or templates during information processing. Evidence that the Skilled group employed templates during the processing of contour map data may have been provided by analysis of the participants' protocols and the move-distance data from the Graphical Analysis. During encoding and recall of map features in the contour map task the Skilled group had included more examples of the procedural codes *relational encoding, inferring height* and *employing specialist schemas* than the Novices. The increased use of these codes by the experienced map readers suggested that they were integrating the map features into prototypical configurations to facilitate information processing. Further evidence for the use of schemas was provided in the move-distance data. The experienced participants had made more entries on their maps at greater distances than 15 centimetres from the previous entry. This suggested that the Skilled group had more regularly encoded and recalled features which were related in semantic, spatial or topographic contexts rather than their close proximity to one another. This finding added support to the evidence of the use of templates by the Skilled group during the processing of contour map data.

The study confirmed that experienced topographic map readers had superior performance for the recall of information from contour maps but this advantage did not extend to non-contour maps or non-contour information on topographic maps. Although confirmation of information chunking during processing of map features was not specifically identified, the Skilled participants appeared to employ cognitive schemas and templates to assist encoding and recall of topographical data.

3.7 Overall Conclusions

Conclusions based on the four research questions are provided below.

Research question 1**:** *Do experienced map readers have better recall for map information than less experienced map users?*

- Skilled map readers did not differ from Novices in the amount of map information recalled from a non-contour map.
- Skilled participants did recall more contour information than the novice group when employed in a contour map recall task.
- Comprehension and recall of map information is dependent on the experience of the map reader and the nature of the task.

Research Question 2: *Do skilled contour map readers have a superior memory advantage for both contour and non-contour information?*

- The Skilled group recalled more contour related data onto their sketch maps but did not differ from the Novices in the amount of feature related information.
- The groups performed equally poorly on the contour related questions possibly due to floor effects.
- Experienced contour map readers have superior recall for contour related data due to their experience and familiarity with the task.

Research Question 3: *Do experienced map readers employ cognitive strategies such as information chunking during encoding and recall of map information?*

- Detailed examination of the Graphical Analysis data did not reveal any group differences in the use of information chunking during encoding and recall.
- The effect size may have been too small, individual differences too great, sketching tasks too heterogeneous, or the strategy was not employed.
- The use of information chunking could not be reliably identified as a cognitive strategy employed by the Skilled group.

Research Question 4: *Do experienced map readers employ cognitive strategies such as templates to assist in the processing of spatial information presented on a map?*

- The Skilled group encoded and recalled features that were related semantically, spatially or topographically and not merely proximally located.
- The experienced participants recalled features more widely distributed than those recalled by the novices.
- The encoding and recall of related features within prototypical configurations by the experienced group provided some evidence of the use of cognitive schemas or templates.

Chapter 4: Evaluation of Skilled Performance in a Map Reading and Recall Task – Experiment 2

4.1 Introduction

The first experiment in this thesis provided evidence that proficient contour map readers performed better than Novices in the task of recalling contour-related information from a contour map. The experiment further demonstrated that the superior memory performance of the Skilled group was limited to the recall of contour data alone and did not extend to the recall of non-contour features within the contour map nor for features presented in a separate examination of a town map.

However, the difference between the performances of the Skilled and Novice groups in the contour map task, although significant, was not large. Also the two groups had not differed in their overall comprehension of their map sketches when measured by their responses to the contour map questions.

In addition, two areas of concern were identified within the experimental design which might have confounded the results. Firstly, all the participants had completed the map recall tasks by studying and sketching the town map prior to the contour map. No attempt had been made to counterbalance the experimental tasks. Secondly, within the Novice group, three participants were not native English speakers and their verbal protocols may have been adversely affected by the additional cognitive demands of providing a commentary in English. Accordingly, a further study was conducted in order to address these concerns and to validate the findings of the first experiment.

This chapter reports the second experiment. In the second section of the chapter a modified experimental design is described which addresses the shortcomings previously identified in the first experiment. The third section provides a detailed description of the experimental procedures and the results are outlined in section four. These results are discussed in section five and summarised in section six. The overall conclusions are presented in section seven.

4.2 Research Design

This section reintroduces the research questions to be evaluated within a similar experimental design to that employed for Experiment 1. The design necessarily incorporates modifications in experimental procedure and participant selection to address the areas of concern subsequently identified in the earlier research reported in Chapter 3.

4.2.1 The four research questions

The first two research questions were evaluated in the original Gilhooly (1988) study to measure performance differences between skilled and novice participants in a map reading task. Questions three and four were introduced in Experiment 1 of this dissertation to investigate the nature of the cognitive strategies which might be employed by experienced map readers to achieve superior performance when recalling map-related data. All four questions were to be addressed in this experiment.

1. *Do experienced map readers have better recall for map information than less experienced map users?*

2. *Do skilled contour map readers have a superior memory advantage for both contour and non-contour information?*

3. *Do experienced map readers employ cognitive strategies such as information chunking during encoding and recall of map information?*

4. *Do experienced map readers employ cognitive strategies such as templates to assist in the processing of spatial information presented on a map?*

4.2.2 The Gilhooly experimental design

In order to answer research questions 1 and 2, Gilhooly and his colleagues conducted two experiments within a single study. Each participant was presented with either a town map or a contour map to study and recall. Between-group differences showed that skilled map readers had better recall when recalling contour features from the contour maps. However, the high-skill group had not differed from the corresponding low-skill groups when recalling features from the non-contour maps or non-contour features from the contour maps, as the authors predicted.

In their second experiment Gilhooly et al. employed a group of high-skill map readers (n = 11) and a group of low-skill participants (n = 10). All the participants studied and recalled only one contour map. Again the high-skill group had better recall for contour-related data.

4.2.3 Selection of the experimental design for Experiment 1

The aim of Experiment 1 had been to combine both the Gilhooly experiments within a modified design in which each participant completed both a town map and a contour map task with provision for detailed analysis of participant performance in each task.

The employment of this design provided the opportunity for both between-group and within-subject comparisons while addressing all four research questions within a single experiment. The full rationale for selecting this design is summarised in section 3.2.4 of the previous chapter.

4.2.4 Selection of the experimental design for Experiment 2

In Experiment 1 the research questions had been satisfactorily addressed although some shortcomings in the experimental design were subsequently identified. Since the primary aim of this second experiment was to validate the results achieved in the earlier experiment it was important to retain the majority of the original experimental procedures introducing only those changes necessary to address the known shortcomings.

To achieve counterbalancing of the experimental tasks, half the participants from each group were scheduled to complete the contour map prior to the town map task while the remainder completed the town map first. To ensure that the results from the verbal protocols were not compromised by the inclusion of participants for whom English was not their first language, all participants recruited for Experiment 2 were native English speakers.

In order to increase the statistical power for the experimental measures, participant numbers in each group were increased to 12 in the novice group and to 14 in the skilled group. In addition, a better differentiation of skill levels between the two groups was achieved by employing a combination of professional cartographic researchers, post-graduate students from a Physical Geography laboratory and third year Geography students within the Skilled group.

Finally, the contour map questions were amended to reduce the level of difficulty and thereby counter the probable ‘floor’ effects evident in the earlier results.

4.3 Method

This section outlines the method employed for Experiment 2 and initially provides a description of the participants followed by details of the materials employed. The experimental procedure is then described and the section concludes with a summary of the data analysis considerations.

4.3.1 Participants

A total of 26 participants were recruited from the University of Sussex and the Ordnance Survey HQ in Southampton to form the Skilled and Novice groups. Of the 14 participants in the Skilled group, nine were recruited from the Physical Geography laboratory and third year Geography undergraduates at the University of Sussex, and five were employees at Ordnance Survey attached to the research department. The Skilled participants were recruited by a circular stipulating that they should be ‘fully conversant with contour maps’ and their map-reading skill was further verified by the ‘Familiarity with maps’ questionnaire. The average age of the Skilled group was 35 (SD 14.9) and three of the 14 were female.

The Novice group was recruited from the School of Informatics at the University of Sussex with a requirement to have a ‘basic knowledge of maps’. The average age of the Novices was 20.8 (SD 1.1) and two of the group were female.

All participants were native English speakers and were volunteers. With the exception of the Ordnance Survey employees, all participants were paid £10.

4.3.2 Apparatus and materials

This section summarises the experimental measures and equipment employed. The majority of equipment was identical to that adopted for Experiment 1. Detailed descriptions are therefore provided only for items which were modified following the first experiment.

4.3.2.1 Materials Retained from Experiment 1

The following test materials were retained and remained unchanged from those employed for Experiment 1:

- The Participant consent form (See Appendix 2)
- Familiarity with maps questionnaire (See Appendix 3)
- Paper Folding test (See Appendices 4.1, 4.2)
- The Rey-Osterrieth Figure copying task (See Figure 3.1, previous chapter)
- Town map (See Appendix 5)
- Town map questions (See Appendix 6)
- Contour map (See appendix 7)

4.3.2.2 Contour Map Questions

The contour map questionnaire employed for Experiment 1 contained eight questions relating to contour data and map detail produced either on participants' sketches or remembered from the contour map. Participants were presented with alternative choice answers and were required to provide a confidence assessment for each answer on a 5-point Likeart scale ranging from '*not really sure (1)'* to '*supremely confident (5)'*. From a maximum possible score of 40 for their confidence-weighted answers both groups had scored less than 25%, with the skilled group (M = 8.9 SD = 5.5) not differing significantly from the novices (M = 6.3 SD = 5.4).

Examination of the answer sheets indicated that both groups had difficulty with three questions relating to minor road and rail crossings (Q 1, Q4, Q8) while no clear patterns emerged for answers to the remaining questions.

As a result these three questions were replaced with questions relating only to main route crossings and contour information directly relevant to the task instructions issued with the contour map exercise. The revised contour map questions employed for Experiment 2 are provided below.

Contour map questions

Please circle your selected answer and indicate your confidence in your answer on a scale of 1 – 5 where 1= not really sure and 5 = supremely confident

1. If you walk South East from Yeoford are you climbing or descending.
2. Is Yeoford at a greater elevation than Lower Town
3. Is Keymelford visible if you are located at Warrens farm
4. Does the road from Yeoford to Warrens farm cross over or under the railway
5. If walking Southerly from Warrens farm which road is the steeper climb, the road through Yeoford or the road through North Down
6. Which road is steeper, the road from Hill Barton to Warrens farm or the road from West Keymelford to Lower Town.
7. Is the highest hill to the South or the North of the railway line
8. Is Neopardy lower than Keymelford or about the same elevation

4.3.2.3 Electronic Graphics Tablet

The Wacom Intuos2™ graphics tablet was retained in this experiment to replicate exactly the experimental procedures adopted for the earlier research and to facilitate the recording of participant sketches using the video camcorder. Due to the complexity of information transferred in the map sketching task, the TRACE software had not proved suitable for the identification of group differences in pause times in Experiment 1 (See Chapter three, section 3.4.4 and section 3.5.4 for a full discussion). However, group differences in the techniques employed for information transfer from map to sketch had emerged when the move distances between pen-up and pen-down events were studied.

Skilled map readers had recorded more pen strokes at distances greater than 15 centimetres from previous pen-stroke activity suggesting that these participants might be integrating features into schemas as opposed to processing features that were merely proximally located. The tablet data was therefore again collected to attempt to identify group differences in encoding and recall patterns.

A Dell Precison M2300 Laptop operating MS Windows XP Version 2002 Service Pack 3 was employed with the Wacom Intuos2™ graphics tablet to provide the portability required for testing away from the University of Sussex.

4.3.2.4 Video and Audio Recording Equipment

Unchanged from Experiment 1 (See 3.3.2.10)

4.3.2.5 Analysis of Verbal Protocols

Participants' verbal protocols had been obtained in Experiment 1 and had provided evidence of group differences in the encoding strategies employed for the contour map task. However, the full list of procedural codes had been produced from the original Gilhooly study in which the map study sequence involved one inspection of five minutes followed by one unlimited recall period.

In Experiment 1 the single study period had been replaced with five separate study periods of one minute, thereby introducing a more fluent process of encoding and recall in which to examine the cognitive processing of map features by the participants. As a result, several of the procedural codes such as '*partitioning – dividing the map into sub-units*' and '*verbal association – using word association as a memory aid*' which described memory strategies employed in the single inspection task were not evident in the protocols for participants engaged in the continuous encoding and recall procedure.

The *reading names aloud* code described the practice of reciting place names during inspection of the map. Although participants had indeed read names in the first experiment, no group differences had emerged in either of the map tasks. It was considered therefore that the mere practice of reading names had not been a reliable indicator of the use of encoding strategies and the code was not included for this experiment.

Similarly, codes describing '*pattern encoding - encoding features according to geometric or familiar shapes*' and '*positive evaluation - assessing personal performance positively*' had appeared only in a few protocols and too infrequently to enable reliable statistical analysis.

Five of the original procedural codes had, however, proved descriptive of the strategies employed by participants in the encoding and recall of features in the earlier experiment. These were retained for Experiment 2 and are provided with their descriptions in Table 4.1.

All the verbal protocols were analysed using the HyperRESEARCH™ software employed for Experiment 1.

Relational encoding	Describing the location of a feature as it relates to other features
Inferring height	Attributing values of altitude or rates of change of altitude
Metacognition	Analysis of personal performance on aspects of cognitive processing
Task reference	Incorporating features of the designated task into the search and encoding processes
Specialist schema	Employment of specialist knowledge to provide enhanced comprehension of the information studied or recalled

Table 4.1 Procedural codes employed for the verbal protocol analysis

4.3.3 Procedure

This section provides an overview of the experimental procedure and a description of the sequence of testing.

4.3.3.1 Overview of Procedure

Participants from the University of Sussex were tested individually at a workstation located in the eye-tracking room attached to the Representation and Cognition Laboratory, University of Sussex. Participants recruited from Ordnance Survey were tested in a meeting room within the ground floor conference area of the HQ building.

As in the earlier experiment, the graphics tablet was sited on the desk in front of the seated participant and a vertical monitor provided the experiment supervisor with a real-time display of participants' sketch maps.

Each participant completed a consent form, a questionnaire to assess their competence with contour maps and two brief tests to control for spatial visualisation ability and spatial memory.

Half the participants then commenced with the town map task while the remainder completed the contour map exercise first. For both tests the map was studied for one minute and then removed. Participants sketched as much detail from the map as they could remember before again inspecting the map for a further minute. After a total of five inspections and associated sketch activity had been completed the participants answered questions relating to the map they had sketched.

Participants' sketch activity was filmed from the monitor during the compilation of their sketch maps while verbal protocols were recorded during both the map inspection and recall phases of each map exercise.

On completion the participants were thanked and with the exception of the OS employees, paid £10.

4.3.3.2 Detailed Sequence of Testing

With the exception of the contour map questions, all materials were identical to those used in Experiment 1. Participants completed the tasks in the order provided below.

.

- Participant consent form
- Familiarity with maps questionnaire
- Paper Folding Test
- Rey-Osterrieth Complex Figure copying task
- First map exercise, *either* the contour map task followed by the revised contour map questions, *or* the town map and town map questions
- Second map exercise with alternative map to that completed in the first task

4.3.4 Experimental design considerations

The experimental design was governed by the requirement to reproduce and verify the results obtained in Experiment 1. This necessitated minimal change to either the materials or the procedures employed for the original research.

However, the number of participants in each group for the first experiment had been low. The group size had been determined by difficulties in recruiting skilled map readers from the university campus and had provided a Skilled group of only eight participants. For this experiment group sizes were increased to 14 for the Skilled participants and to 12 in the Novice group. The advantage of increased group size provided sufficient participant numbers for within-group comparisons for the two counterbalanced map tasks while improving the statistical power in the between-group comparisons. It had also been anticipated that inclusion of participants from Ordnance Survey might increase the mean level of map-reading ability in the Skilled group.

Data analysis procedures for the between-group comparisons remained unchanged from those employed in Experiment 1.

4.4 Results

The results are reported in four sections. The first section provides details of participant scores for the Familiarity with maps questionnaire and the two tests of spatial ability. Section two contains results for the town map task and section three the results for the contour map task. Section four provides results from the analysis of data from the participants’ protocols.

4.4.1 Familiarity with maps questionnaire, Paper-folding and Rey-Osterrieth Complex Figure copying tasks.

Map-reading skill was measured by the participants’ responses to the Familiarity with maps questionnaire. From a possible 20, the Skilled group ($M = 17.8$ $SD = 2.4$) scored significantly higher than the Novices ($M = 13.2$ $SD = 3.9$) and inspection by ANOVA confirmed this difference was significant $F(1,24) = 2.9$, $p < .01$. All the Skilled participants achieved a score of 14 (70%) or above.

The Paper folding and Rey-Osterrieth Complex Figure copying tasks had been employed to control for spatial abilities and spatial memory performance. The two groups were of similar abilities in the Paper folding test with the Skilled group correctly identifying solutions to approximately two-thirds of the ten problems (M = 6.7 SD = 1.3). This was marginally less than the Novice group (M = 7.1 SD = 1.8) but not significantly so F(1,24) = .542 p = .47. For the Complex Figure copying task the maximum achievable score had been 32. The groups did not differ significantly in this task with the Skilled participants (M = 26.3 SD = 4.4) closely matching the Novices (M =25.3 SD =2.5). Again this result was not significant F(1,24) = .44, p = .51.

These results identified group differences in map-reading skill levels but confirmed similar group abilities for general spatial memory tasks.

4.4.2 Town map task

The town map task was included in the experiment to address the first research question: *Do experienced map-readers have better recall for map information than less experienced map users?* It had been anticipated that the two groups would not differ in their performances when engaged in a task requiring minimal map-reading skill.

Experimental instruments: Participants' sketch maps and town map questions

The town map sketches from each participant were assessed for completeness and accuracy. Each feature correctly named and located was allocated a full mark, while features drawn but unnamed, or features named but incorrectly located were awarded a half mark. The maximum score possible for a complete and accurate sketch was 33.

As predicted the Skilled participants transferred a similar number of features (M = 22.9 SD = 2.8) onto their sketches as the Novices (M =24.1 SD = 3.8) and the groups did not differ significantly F(1,24) = .776, p = .39.

Answers to the eight town map questions had been confidence-weighted to provide a possible maximum score of 40. The Skilled group (M = 27 SD = 9.5) were marginally better than the Novices (M = 25.6 SD = 11.2) in recalling detailed information from their town map sketches but not significantly so F(1,24) = .122, p = .73.

Results from the town map task confirmed that the two groups had similar performance levels in their recall and comprehension of detail in the town map.

4.4.3 Contour map task

The contour map task addressed the second research question: *Do skilled contour map readers have a superior memory advantage for both contour and non-contour information?*

Experimental instruments: Participants' sketch maps and contour map questions

Participants' sketches of the contour map were marked using similar procedures as those employed for the town map where each feature scored one point for being correctly named and located. However, since contour features were unnamed, they were awarded one mark if they were accurately located. Since contour features were depicted as contour lines or written descriptions of the terrain, both formats were accepted. Where spot heights were included on the map sketch, a score of .5 was awarded for each entry. The maximum score for contour and non-contour data was forty.

The Skilled group recorded significantly more features (M = 26.5 SD = 3.3) on their contour map sketches than the Novices (M = 22.4 SD = 3.6), $F(1, 24) = 9.4$, $p < .01$. However, when the recorded information was separated into contour and non-contour features, it was evident that the Skilled group had achieved their superior performance in the number of contour features recorded and had not differed significantly from the Novices for non-contour features (Table 4.2).

Feature type	**Group Mean (SD)**		**Significance**
	Skilled	Novice	
Non-contour	16.1 (2.4)	15.5 (2.4)	ns
Contour	10.4 (3.2)	6.88 (2.37)	**
Combined total	26.5 (3.3)	22.4 (3.6)	**

**Significant at .01 level

Table 4.2 Group means (SDs) for number of features recalled in contour sketches

Participants were tested for comprehension of their sketches by providing answers to the amended contour questions and included a confidence rating for each response. From a possible score of 40, the Skilled group scored just under 50% (M =18.9 SD =

5.9). This was significantly higher than the Novices score (M = 9.4 SD = 7.6), $F(1, 24) = 12.5$, $p < .01$.

The results provided confirmation that the Skilled group of map readers recorded more contour-related information on their sketch maps than the Novices and provided more accurate responses when responding to the contour map questions.

4.4.4 Test for task-order effects

The two map tasks had been completed using similar procedures and it was possible that participant performance may have been affected by the order in which the maps were studied. At the outset, an equal number of participants from both groups had been presented with either the town map or the contour map as the first exercise. Within-group comparisons were conducted by ANOVA and no significant differences were found between recall performances for participants who completed the contour map first and those who completed it following the town map. Detailed results are provided in Tables 4.3 and 4.4.

Features recalled	**Within Skilled Group Means (SDs)**		**Comparisons**	
	Task sequence			
	Contour first	**Contour second**	**F(1,12) value**	**Significance**
Contour	10.9 (3.1)	9.8 (3.5)	.372	.553
Non-contour	15.4 (2.7)	16.9 (2.0)	1.25	.285
Combined	26.4 (3.5)	26.7 (3.3)	.038	.849

Table 4.3 Skilled participants within group comparisons for task-order effects

Features recalled	Within Novice group Means (SDs)		Comparisons	
	Task order			
	Contour First	Contour Second	F(1,10) value	Significance
Contour	7.6 (2.7)	6.36 (2.17)	.783	.397
Non-contour	15.7 (3.3)	15.4 (1.7)	.034	.857
Combined	23.3 (5.2)	21.8 (1.9)	.506	.493

Table 4.4 Novice participants within group comparisons for task-order effects

For completeness, participant performance on the town map sketches was also examined for task-order effects. No significant differences $F(1,12) = 2.17$, $p = .166$, were found between the content and accuracy of the information recorded on the Skilled participants sketches who studied the town map first and those who studied it second. The Novices were similarly unaffected by the task order and analysis of their scores also provided a non-significant result $F(1,10) = 1.13$, $p = .313$ for between task comparisons.

4.4.5 Graphical Analysis

Research questions three and four aimed to establish if experienced map readers employed strategies such as information chunking or templates when encoding map features. Analysis of the TRACE data was therefore conducted to investigate possible group differences in the compilation of participants' contour map sketches which may have revealed the use of different cognitive strategies.

Experimental instrument: Graphical Analysis of sketch map data

In Experiment 1 the Skilled participants had made entries to their contour map sketches at a distance of 15 centimetres from the previous pen-stroke more frequently than the Novice group. One interpretation of this finding was that the Skilled participants may have been encoding features by grouping them according to semantic properties and not merely recalling features in close proximity to each other.

For this experiment all participants used the graphics tablet for the copying tasks but six TRACE protocols recorded on the portable Laptop computer were subsequently found to be incomplete and could not be included in the analysis. Accordingly, Graphical protocols from the remaining 20 participants, 10 from each group, were analysed and when inspected showed that the Skilled group made more entries to their contour map sketches at a greater distance from the previous pen-stroke than the Novices. At 100 pixels (3cm) the two groups did not differ significantly in the instances of pen-up to pen-down distances with the Skilled group (M = 97.3 SD = 24.5) recording more than the Novices (M = 76.7 SD = 29.8) but not significantly so, F(1,18) = 2.85, p = .11). At 200 pixels (6cm) the Skilled group (M = 70.2 SD =13.7) had significantly more instances than the Novices (M = 49.1 SD = 13.2) F(1,18) = 12.2, p < .01. At the 300 pixels (9 cm) threshold the groups again differed significantly with the Skilled (M = 48.4 SD = 6.7) count above the Novices (M =37.2 SD = 9.3), F(1,18) = 9.58, p< .01.

At 400 pixels (12cm) the group differences were smaller but just significant F(1,18) = 4.6, p < .05 with Skilled scores at (M =35 SD = 7.3) and Novices at (M = 28.1 SD =8.1). At 500 and 600 pixels the Skilled group scores were ahead of the Novices but not significantly, F(1,18) = 3.6, p = .074 and F(1,18) = 1.23, p = .28 respectively. The results are provided for each threshold in Figure 4.1.

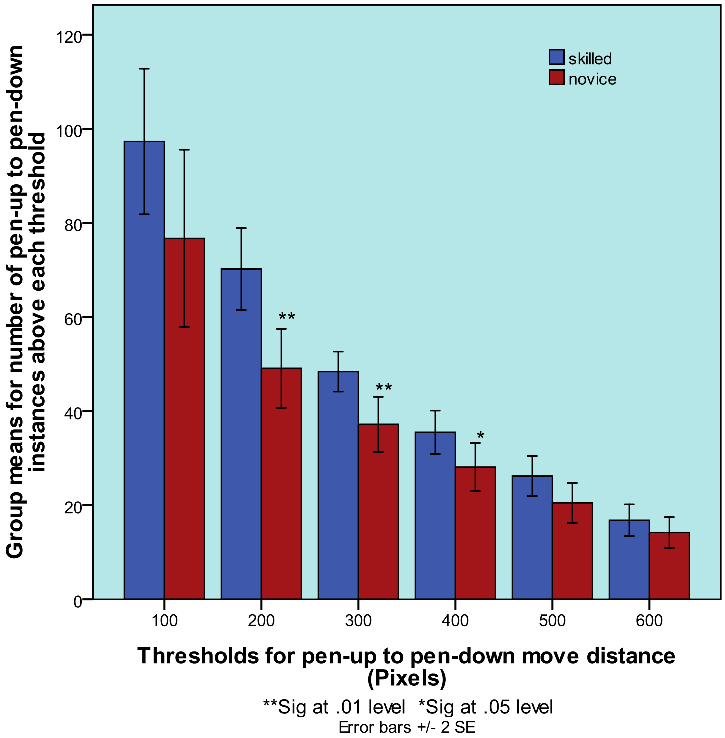


Figure 4.1 Group Means for between pen-stroke move distances at 100 pixel thresholds

The results indicated that the Skilled participants entered data on to their sketches at greater Euclidean distances from the previous entry when compared to the Novice group. This result supported the findings in Experiment 1 although did not exactly replicate them. Where the Skilled group had made significantly more entries than the novices at or above a distance of 15 centimetres in the earlier experiment, in this later research the higher activity levels of the Skilled group were statistically significant only between the 200 and 400 pixel (6 to12 centimetres) thresholds. Nevertheless, this analysis clearly identified that the two groups had differed in the practical procedures they had employed to compile their contour sketches.

The Graphical Analysis data provided detailed measurements of the pause times between pen-strokes. Participants engaged in sketching the contour map might be expected to add features contained within an information chunk with pause durations of less than one second. Pauses above one second might therefore have indicated chunk boundaries. All the participants had adopted an industrious and fluent approach to the copying task and 80% of their pen strokes were conducted with pause intervals of less than one second. Comparisons of the percentage of pauses occurring below the .1, .25, .5 and one second thresholds identified highly similar patterns of activity and no differences between the groups.

The percentage of between pen-stroke pauses at the two second interval was lower for the Skilled group ($M = 13.4$ $SD = 4.9$) when compared to the Novices ($M= 14.5$ $SD =4.3$) but not significantly so $F(1,18) = .265$ $p = .613$. The Skilled group registered fewer pauses than Novices at each of the 3, 4, 5, 10 and 20 second thresholds but the differences again did not reach significance.

Thus, where the original Gilhooly research had reported that during recall the high-skill group had registered fewer pauses above one second than the low-skill group this experimental procedure did not reproduce this finding at a significant level. Instead the results matched those reported in Experiment 1.

However, Gilhooly had also reported that his groups had not differed in the between-pen movement distances during production of their sketches. This experiment clearly demonstrated that significant between-group differences had occurred.

4.4.6 Protocol Analysis

Participants' verbal protocols were examined for evidence of the use of cognitive strategies such as information chunking or templates during the processing of spatial information in support of the third and fourth research questions.

Experimental instrument: Analysis of participants' verbal protocols

Instances of the use of the procedural codes described in Table 4.1 were collated from the participants' verbal protocols for each of the two map tasks.

When studying and recalling features in the town map the Skilled group employed the spatial relationships of features to other map features as an encoding strategy (*relational encoding*) on over 20 occasions (M = 22.1 SD =9.3). Although the Novices adopted this procedure more often (M = 26.8 SD =8.2), the groups did not differ significantly $F(1,24) = 1.81$, $p = .192$.

Both groups made few references to the experimental task (*task reference*) in their protocols with the Skilled group (M = 2.5 SD = 1.73) marginally ahead of the Novices (M = 1.5 SD =.71) but not significantly so $F(1,24) = .56$, $p = .49$. Evidence of participants analysing their thought processes during the town map exercise was also sparse. *Metacognition* scores for the Skilled group (M = 1.25 SD =.5) were similar to the Novices (M = 1.5 SD = .71) and did not differ significantly $F(1,24) = .267$, $p = .63$.

The nature of the task was not conducive to the use of *specialist schemas* and no analysis was conducted for this procedural code.

The two groups, therefore, had not differed in their use of encoding procedures for the town map task.

When studying and reproducing the contour map however, the groups did differ in their encoding strategies. The use of *relational encoding* was again adopted frequently by the Skilled group (M = 20.0 SD = 12.3) but significantly less often, $F(1,24) = 10.95$, $p <.01$, by the Novices (M = 8.0 SD = 2.6). Incidences of *inferring height* were far higher in Skilled group (M = 29.2 SD =12.1) compared to the Novices (M= 12.9 SD =6.9) again producing a significant difference $F = 17.02$, $p < .001$. Results for the remaining codes showed no significant differences between the groups although the *use of specialist schema* generated higher scores (M = .86 SD =1.2) for the Skilled participants and (M = .17 SD = .38) for the Novices and were close to significance at F(1,24) = 3.81, p= .063. Group means for these five codes are provided in Figure 4.2.

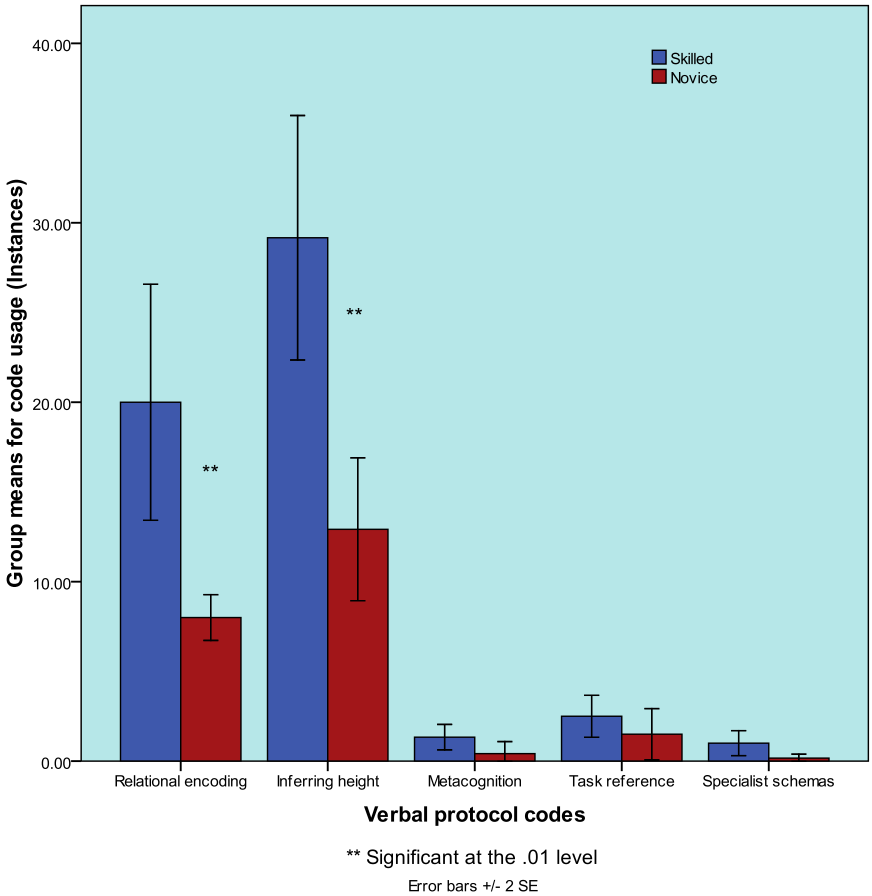


Figure 4.2 Group means & SDs for protocol code usage in the contour map task

The two groups therefore differed significantly in their use of the *inferring height* and *relational encoding* codes in line with the results reported in Experiment 1. Both groups, however, again had far higher scores for these codes than the participants in the original Gilhooly study. While map reading competence in all the Experiment 2 participants may have been higher than the high-skill and low-skill groups in the earlier study and this might have affected these results, it was considered more likely that the continuous encoding and recall cycle designed into this experiment had again captured more of the iterative processing steps employed by participants during the map inspection and recall tasks. The close resemblance of the scores for both codes in Experiment 1 and 2 provided further support for this assumption.

When a within-group comparison for the use of *relational encoding* was conducted across the town and contour map tasks a significant effect for task was also evident for the Novice group $F(1,24) = 17.95$, $p < .01$. The results for *relational encoding* across both map tasks are provided in Figure 4.3.

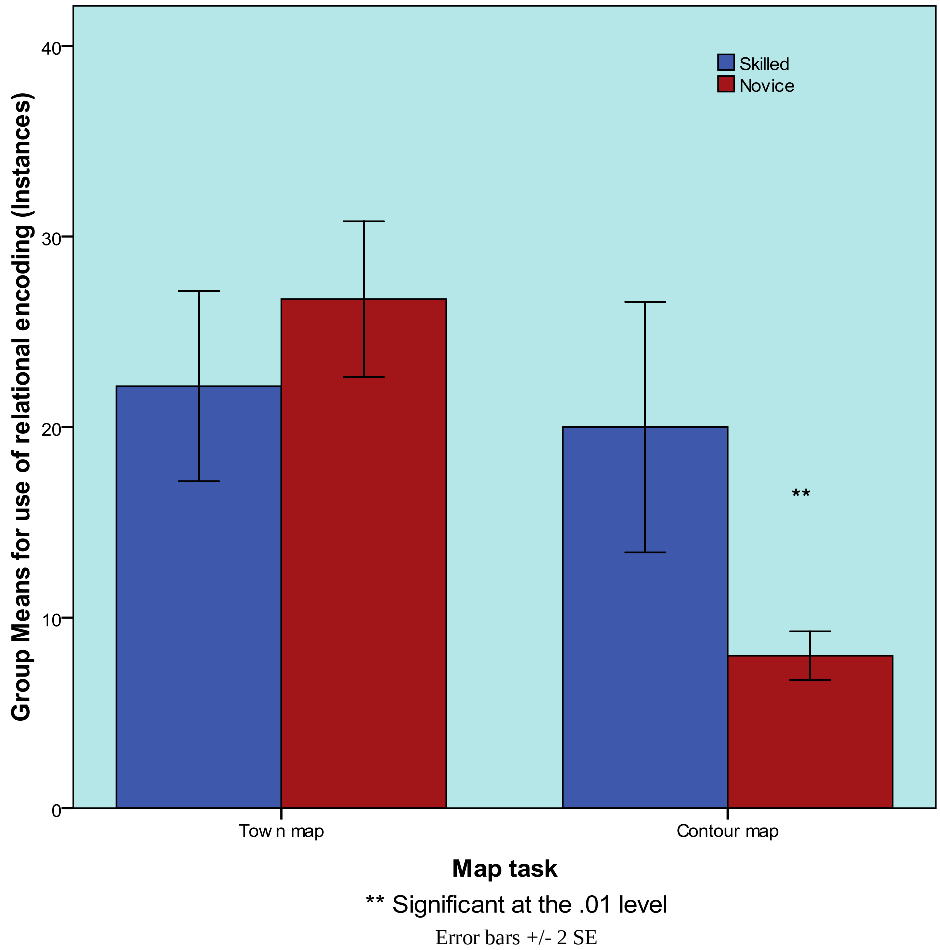


Figure 4.3 Group means & SDs for protocol code '*relational encoding*'.

From the results it was evident that the Novice group frequently relied on the cognitive strategy of processing features according to their spatial relationships with other map features for the town map exercise. However, when studying and recalling features from the contour map the Novices failed to adopt this strategy no matter which order they completed the map tasks. By comparison, the Skilled group remained consistent in their usage of *relational encoding* across both tasks.

Closer inspection of the verbal protocols for the Skilled group (each example contains the recording reference and elapsed time) revealed descriptions which included

‘*Neopardy is on the slope*’ (p2, 11.27.5 – 11.30.3) and ‘*It’s a lot steeper just South of Yeoford*’ (p25, 06.31.3 – 06.35.2) also ‘*The peak by Brandise cross*’ (p4, 03.34.9 - 03.40.4) and ‘*Down by Martin’s moor that’s a steep bit as well*’ (p4, 03.49.1- 03.53.6) all of which provided evidence that Skilled participants were consistently integrating contour-related information with other associated map features. Although the Novices were interpreting the contour data ‘*The gradient is pretty steep here*’ (p11, 05.24.5 – 05.27.1) and ‘*It’s 125 (metres) here*’ (p14, 02.15.4 – 02.12.6) there were far fewer examples of contour and non-contour feature integration.

Use of the *inferring height* code included simple descriptions of the topographic features ‘*From the contour lines it is not very steep at all*’ (p4, 06.25.2 – 06.29.7) to more complex interpretations ‘*There’s a long valley with some steep slopes around*’ (p1, 07.04.2 – 07.07.9) and ‘*I can visualise the shape…there is a high ridge*’ (p1, 12.16.2 – 12.22.4). The descriptions were similar across all participants but with significantly fewer references to height in the Novice group.

Examples of *task reference* included ‘*There’s a pub there which would be a good place for walkers to stop*’ (p7, 07.39.5 – 07.43.9) and ‘*It’s going to be a real climb through those woods*’ (p1, 06.45.7 – 06.49.1) and were evident in both groups of participants as were examples of *metacognition,* ‘*I’m terribly bad at remembering names*’ (p23, 09.23.4 – 09.27.1) and ‘*I’m not really taking in any new information I’ve got the main features*’ (p7, 14.11.2 -14.15.8).

The use of *specialist schemas* was almost exclusively restricted to the Skilled group and included statements such as ‘*I’m going to put the river network in because that will define the valleys*’ (p23, 05.01.6 – 05.07.7) and ‘*There’s a flood plain down here so it’s quite low*’ (p9, 12.52.1 – 12.55.5).

4.4.7 Interrater reliability for contour map marking and verbal protocols

The marking of contour features on participants’ sketches had required the researcher to assess the accuracy of sketched or scripted features and their locations. Since this exercise had occasionally required subjective interpretation of participants’ data, 13 contour maps were marked by an independent marker and the results compared with the original scores. The Pearson coefficient for this comparison, $r = .727$, indicated a significant correlation at $p < .01$.

Comparisons of Protocol Analysis scores from 10 of the map exercises were also conducted by another independent assessor for each of the five main code categories. Marking was found to be highly consistent and comparisons provided significant correlations for three of the individual categories. The scores for *metacognition* evaluation were affected by the very low number of instances and produced a non-significant result. However, a significant correlation was observed in an overall comparison which included all codes. Results are provided in Table 4.5.

Code Category	**Pearson coefficient (r)**	**Significance**
Relational encoding	.97	*
Inferring height	.98	**
Task Reference	.94	ns
Metacognition	.17	ns
Relational encoding (Town)	.98	*
All categories	.96	**

*Significant at .05 **Significant at .01

Table 4.5 Between-marker correlations for Protocol Analysis codes

The comparisons of assessors on both the contour data and the Protocol Analysis data therefore showed a reliable level of consistency between the individual scores for the experimental measurements in each of the tasks.

4.5 Discussion

4.5.1 Participants' map-reading experience and spatial skills

The selection of participants for the Skilled group had been determined by the method of recruitment. All were either experienced students of geography or members of the research department at Ordnance Survey. As a result their map-reading skills were well above the standard of the Novices as confirmed by the analysis of the 'Familiarity with maps' scores. Although the experimental tasks had been designed to minimise any gender effects, the group membership was nevertheless balanced with three females in the Skilled group and two in the Novices. The participants did, however, differ in their mean ages with the skilled group 15 years above that of the novices.

No differences between the groups were found in the two tests of spatial skill and memory.

4.5.2 Discussion of the first research question

Experimental instrument: Town map sketch and questions

The first research question asked if experienced map readers had better recall for all map information than Novices and was addressed by the results of the town map task. It was anticipated that the two groups would not differ in their ability to complete a rudimentary map sketch from a planimetric map. In line with the findings in Experiment 1, the two groups transferred similar amounts of data to their sketches and when answering the town map questions achieved accuracy scores which were closely matched. These results supported findings in the expertise literature which have demonstrated that skilled map readers conducting map-reading tasks which do not require specialist knowledge have little or no advantage over inexperienced participants.

4.5.3 Discussion of the second research question

Experimental instrument: Contour map sketch and contour map questions

The second research question concerned the nature of information remembered by skilled map readers. It was anticipated that experienced contour map users would have superior recall for contour data but not necessarily for non-contour features when compared to the less experienced participants. The results from the contour map sketches demonstrated that the Skilled group reliably outperformed the Novices on the amount of contour features recalled on their sketches and with this information were able to make more accurate responses to the contour map questions.

Again, the Skilled group had not recalled a higher number of non-contour features than the Novices providing further evidence that features processed without the need for any specialist knowledge merely tested the spatial memory of participants and on this measure it had been reliably demonstrated, the two groups did not differ.

The contour map questions had been revised from the set used in Experiment 1. Seven of the eight questions now required participants to have a comprehensive understanding of the topography in their sketch maps before they could provide a correct response. Both groups had performed poorly at this task in the earlier research, but in answering the revised questions, the Skilled group now reliably outperformed the Novices.

Evidence from both experimental instruments thus converged in identifying that the Skilled group had differed from the Novices specifically and predominately in the processing and comprehension of contour features.

This finding in itself was unremarkable since the Skilled group had been selected for their experience with contour maps. However, the result has particular relevance for the more detailed investigation into how participants might have been processing the contour features as described in the following sections.

4.5.4 Discussion of the third and fourth research questions

The third and fourth research questions enquired if information chunking or the use of templates were cognitive strategies employed by skilled map readers.

Experimental instruments: Contour map data, Graphical Analysis of participants' sketch maps and verbal protocols

The data from participants' sketch maps again provided a detailed record of pen-stroke activity and further analysis identified the pause times between each pen stroke. It had been hypothesised that Skilled participants might integrate features into chunks during encoding. If the information chunks contained more features than those processed by the Novices this would result in larger chunks and correspondingly fewer long (inter-chunk) pauses within the Skilled group.

In Experiment 1, however, it had not been possible to define precisely what pause duration might delineate a chunk boundary. For a task in which the contour information transferred to the sketch may be in a variety of forms such as spot heights, script or contour lines, pauses between the addition of features possibly widely dispersed on the sketch but nevertheless within the same information chunk might be conducted with pause durations of greater than one second. Similarly, given the continuous nature of the encoding and recall procedure, information from one chunk might be completed and sketching of a feature belonging to the next chunk commenced with a pause duration at or under one second. Inter-chunk pause durations were therefore subject to large variations in participants' individual recall performances and the specific task element being completed. Accordingly it was possible that *inter*-chunk and *intra*-chunk pauses may have overlapped when group comparisons were made whereby pause durations would no longer have been reliable indicators of chunk boundaries. This interpretation might have explained why no significant differences were found between the two groups for this measure in the earlier experiment.

Although the sketching tasks were identical to those employed in the earlier experiment, the difference in skill levels between the groups was greater for this second experiment. The pause durations obtained from the TRACE data were therefore examined to establish that group comparisons had not differed from those observed in Experiment 1.

Pen-stroke activity in which the pen-up to pen-down pauses were less than one second accounted for 80% of recorded pauses across all participants. No group differences had been apparent at the one second threshold. However, above two seconds the Skilled group had marginally, but not significantly, fewer pauses. Although this trend was observed at the 3, 4 and 5 second threshold values the group differences were not significant. The findings replicated the earlier results and between-group comparisons of pause threshold levels were again not identified as reliable indicators of chunk boundaries in a map sketching task for the reasons discussed earlier.

Supporting evidence for the use of information chunking by the experienced map-readers was therefore sought in the contour map results, move-distance data and protocol analyses. The Skilled group had produced more comprehensive sketches based on the inclusion of superior numbers of contour features. In their protocol analyses the Skilled group had also demonstrated a greater awareness of the contour features in their *inferring height* scores but importantly had encoded features according to their relationship with other features, both contour and non-contour, more frequently than Novices. The increased efficiency for recall by the Skilled group might therefore have been achieved by the integration of related features into single elements during encoding.

From the move-distance data a clear pattern had emerged in which the Skilled group were adding pen strokes to their sketches at greater distances apart than those appearing on the Novices sketches. Since the Skilled group had more contour features and contour features generally involved longer pen strokes (and corresponding between pen-stroke movements), it was possible that for this reason alone the Novices with fewer contour features would also have fewer widely displaced entries on their sketches. Equally, it was possible that the more experienced map readers were grouping features not by their close proximity to each other but according to semantic similarities. On recall, the grouped features might have been more widely distributed than items clustered within one area of the map. The grouping of individual features into one larger element and the efficient encoding and recall of features according to familiar grouping categories are both cognitive strategies associated with information chunking.

However, members of the Skilled group were also more efficient at integrating the contour features. Examples from the verbal protocols such as '*two valleys either side of a spur*' (p 22, 03.59.2 - 04.04.1) and '*the river's in a valley with another valley to the left and a hill going up to Yeoford*' (p 3, 00.36.7 - 00.48.7) suggested that the Skilled participants were constructing a three-dimensional representation of the terrain in which the spatial relationships of contour and non-contour features were integrated. Grouped features such as valleys and spurs represented by contour patterns familiar to the Skilled group were identified not merely as individual features but also for their complimentary relationships with adjacent features in the wider landscape. The ability of the Skilled participants to build and describe complex representations of the terrain being studied might have been facilitated through a cognitive strategy of matching the contour patterns with prototypical topographical representations already encountered and learnt.

Similarly, if contour features were recalled as integral elements of the overall relief pattern, entries to the map sketches might be based on items remembered within a broad topographical representation where features would be more widely dispersed than those recalled from a single location. Both of these accounts were compatible with the experimental results and both lent support to the hypothesis that the Skilled group employed templates when processing individual features within complex contour data during encoding and recall.

4.6 Summary of Findings

The experiment had two primary aims. Firstly, the results of the Gilhooly et al. (1988) study were to be replicated and secondly the shortcomings in Experiment 1 were to be addressed and the earlier results verified within a modified experimental design.

In this study the Novice and Skilled groups did not differ in the experimental measures for the town map task confirming that experienced contour map readers had no advantage over less experienced participants when the experimental task did not draw on specialist knowledge or practices. However, in the contour map task the Skilled group did recall more contour features than Novices. They were also significantly more accurate with their answers to the modified contour map questions, thereby demonstrating the anticipated advantage for the recall of contour data. These results replicated Gilhooly's main findings and identified that map-reading expertise was dependent on the task and the relevant experience of the participants.

The findings in this experiment improved on those observed in Experiment 1 by identifying between-group differences for the revised contour map questions. This may have been achieved by the increased emphasis on contour details in the revised questions, a greater between-group difference in skill levels or better statistical power provided by an increase in the number of participants in comparison to the first experiment. The revised questions were considered the most likely reason although all three factors were probably relevant. No within-group differences were found for task-order effects when the counterbalanced map results were compared.

In reporting the encoding and recall procedures adopted by the participants, the results closely matched those in Experiment 1, but again differed from those reported by Gilhooly for two of the experimental measures. These were for pause durations above one second and the move distances between pen strokes.

From observation of the participants' video recordings, Gilhooly had observed the number of times participants' pens did not move for more than a second during the sketching of their contour maps. The Skilled group had significantly fewer pauses above one second leading to the suggestion that fewer pauses corresponded to the retrieval of larger chunks.

In both Experiments 1 and 2 the pause data was inspected at 11 threshold values between .1 of a second and 10 seconds but no significant group differences were identified.

Possible explanations for these findings were initially presented in the summary of findings in Experiment 1, but two of these are considered most relevant to the current experiment. Firstly there may have been no between-group differences in the use of chunking as a cognitive strategy. This was possible and could not be entirely ruled out although possible evidence of chunking was observed in two other experimental measures. Secondly, the heterogeneous nature of the information transferred in the sketching task and individual variations in sketching speeds may have resulted in the overlapping of *inter*- and *intra*- chunk boundaries such that between group differences were masked. If this had occurred, simple measurements of participants' pause durations during completion of such a complex task would not have identified information chunk boundaries in a between-group comparison. The Gilhooly study had not defined the duration of inter-chunk boundaries for map-related information and had employed a relatively crude measurement of a single 'all pauses above one second' threshold. It could be argued that the two detailed inspections of TRACE data at 11 increments in Experiment 1 and 2 had provided a more comprehensive examination of participants' sketch activity for the contour map. Results from this experiment thus suggested that inter-chunk boundaries were subject to considerable variation based on the diversity of the task elements and participants' individual sketching speeds and were unlikely to have been encapsulated in a simple 'more than one second' definition.

Experiments 1 and 2 also diverged from the Gilhooly findings in the between pen-strokes move distances. Where Gilhooly found no differences in move distances for his high-skill and low-skill groups, Experiment 1 found the experienced map readers made significantly more entries to their sketches at distances more than 15 centimetres apart and this result was replicated in Experiment 2 although only at distances up to 12 centimetres.

Participants' protocols revealed that the Skilled group encoded the spatial inter-relationships of features more frequently than did the Novices, suggesting that some features were being paired or grouped during processing. Since the move distance data indicated Skilled participants were adding features to their sketches at distances apart greater than did the Novices, the features may have been grouped for their semantic similarities rather than for their proximity to adjacent features. Processing features with common semantic properties by grouping them as a single element could be explained by the Skilled groups' use of information chunking as a cognitive strategy.

The Skilled group also integrated contour features during encoding and then constructed and described three dimensional representations of the studied topography from the complex contour data. The rapid and accurate processing of the contour features was consistent with the use of cognitive templates in which complex contour configurations were held in memory and recalled when familiar contour patterns were encountered and recognised in the map data.

Experiment 2 again identified the recall advantage for the Skilled group in the contour map task within an improved experimental design. The experiment provided further evidence to support the hypotheses that skilled map-readers may employ cognitive strategies such as information chunking and the use of templates when encoding and interpreting contour map data.

Chapter 5 Expert Performance in a Map Comprehension Task of Physical Boundaries – Experiment 3a

5.1 Introduction

The third study reported in this thesis differs from the two studies reported in the previous chapters in two important areas. Firstly, it is a study of *expert* as opposed to *skilled* performance in a map reading task. Secondly it is a more focused examination into the nature of information processed by experts engaged in a map comprehension task.

The previous studies had demonstrated that skilled map users employed cognitive strategies to facilitate the processing of familiar data. They had also provided evidence that the experienced map readers had integrated features and contour data during encoding and recall to provide a more comprehensive understanding of the terrain. The evidence from both the Protocol Analysis and the Graphical Analysis was consistent with the use of prototypical configurations or templates by the experienced group.

While this was an important finding, the experimental design had not facilitated further investigation into the constitution of the grouped features. More specifically, it had not been possible to answer the question: *What criteria were the experienced group using when integrating single features into groups for inclusion into their templates?*

The aim of this study, therefore, is to examine the nature of both the explicit and implicit knowledge employed by expert map readers during the processing of map information.

Following this introduction, the second section of this chapter addresses the factors considered in selecting a research design. The third section provides a full description of the experiment. The results are presented in the fourth section and a discussion of these results is contained in section five. A summary of the experimental findings is provided in section six and the overall conclusions are outlined in section seven.

5.2 Research Design

This section presents the research questions to be addressed. The literature which relates specifically to the nature of the information processed during a map reading exercise is then briefly reviewed. The study by Linhares & Brum (2007) is examined for its suitability for adaptation to a map reading task and the experimental design for the current study is described together with the justification for its selection.

5.2.1 The three research questions

The first research question was examined in the previous study of skilled map readers and is repeated for completeness in this study of expert performance. Research questions two and three have not been addressed in previous studies and are central to the research conducted in this thesis.

1. *Do expert map readers employ cognitive schemas such as templates when engaged in a map comprehension task? and if so:*

2. *Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping features according to familiar patterns?*

3. *Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping features according to abstract roles?*

5.2.2 Literature relating to the use of cognitive schemas by experienced map users

There is reliable evidence that experienced map readers employ cognitive schemas when they are memorising map data (Chang et al., 1985; Davies, 2005; Gilhooly et al., 1988; Kent & Cheng, 2008; Thorndyke & Stasz, 1980). However, little is known as to the exact nature of the information processed within these schemas.

Early descriptions of Template theory (Gobet, 1997; Gobet & Simon, 1996) described the chess Grandmasters' technique of pattern matching familiar board layouts held in LTM with newly encountered chess board configurations during the memorising of chess pieces. Linhares & Brum (2007) have since questioned the importance of pattern recognition in the encoding of chess positions. Instead, they suggest that experts use the abstract roles adopted by each piece due to its position on the board and its relation to adjacent pieces. These are fundamentally different interpretations of how information regarding the perceived chess board may be processed.

The two apparently contradictory approaches are now examined for their implications for map-reading expertise.

5.2.2.1 Pattern Recognition, Information Chunking and Template Theory

Fernand Gobet (1997) has provided Template theory as a description of the information processing employed by chess Masters during their appraisal of a chess board. To summarise the theory briefly: Chunks of information (containing no more than 5 or 6 pieces) are maintained in Long Term Memory (LTM) and accessed through a discrimination net. Chunks which are frequently encountered eventually evolve into more complex structures or templates and these are used by skilled players to match board layouts with those held in LTM to identify opportune moves. Templates are also employed during forward search when movement of pieces is simulated to progress the play on to identifiable board configurations from which further strategies may be developed.

Template theory overcomes the shortcomings of Chunking theory by introducing the concept of slots within the templates. Within these slots tactical and strategic information may be stored relating to the configuration of pieces encoded in the templates. The information processed is therefore not limited solely to the board layout alone.

In sum, Template theory provides a convincing account of how complex spatial representations may be recognised, interpreted, encoded and recalled. Although a facility to encode strategic information within slots in the templates is included, the theory is predominately a ‘pattern recognition theory of expert problem solving’ since templates store patterns and these are the conduit for the rapid processing of information between LTM and the surface search.

Gobet & Simon (2006) have reinforced this description by claiming that the initial recognition processes provided by Template theory are more important than the associated search and evaluation, particularly in time limited competitions. This view however is not supported by the work of Chabris and Hearst (2003). These authors found that Grandmasters made a greater number of costly errors as their times for search and analysis were reduced and concluded that swift pattern recognition is a key component for chess skill but detailed analysis was of equal importance.

Yet while there is some debate on the relative importance of the separate roles of pattern recognition and analysis in chess there is much consensus that the use of pattern matching and templates provides the basis for rapid and efficient information processing by experts.

In the earlier literature discussed in Chapter 2 the similarities between processing of complex spatial information in a chess-playing scenario and the task of map reading were compared. Gobet (1997) has specifically noted that the task of playing chess demands an interaction of perception, memory and knowledge organisation to direct the search for meaningful patterns. We have already seen that these processes are similar to those employed by skilled map users.

If pattern recognition is a core component of superior information processing in skilled chess Masters then it may be equally relevant in the acquisition and application of expertise in map reading and comprehension.

5.2.2.2 Encoding Chess Positions by the Use of Abstract Roles

Alexandre Linhares (2005) has provided an account of chess expertise which questions the claim of Template theory that pattern recognition determines the rules for encoding chess pieces. Instead, the author suggests that individual chess pieces and chunks of pieces are encoded according to the abstract role they perform.

In his revision of Template theory, Linhares agrees that chunks and templates are the method by which information in LTM is compared with the information processed during visual search. However, the author maintains that the information contained in either the chunks or templates does not represent visual patterns of familiar groups of pieces. Where Chase & Simon (1973b) had suggested that a method of activating chunks had been their immediate attack or defence relationships within the chunks, Linhares goes much further by suggesting it is the strategic and tactical information itself which constitutes the chunk.

To provide clarification of this concept, Linhares introduces the term 'distance metric' which is composed of two separate dimensions. Chess pieces may be positioned close to one another in the Euclidian sense such that there is little physical distance between them in the board layout. This is the first dimension in the distance metric and is generally associated with chunk delineation in Gobet's pattern recognition theory.

However, pieces may also command a position in which they present either an immediate threat or a threat in one, two or more moves. In this context it is the immediacy of the threat in playing time (measured in moves) that represents the closeness and the urgency. This constitutes the second dimension of the distance metric and is not related to physical proximity. A knight unable to threaten a king for at least three moves is thus perceived at a (relatively) safe distance of three moves. A bishop at a greater Euclidian distance may nevertheless be an immediate, and therefore closer, threat.

Within this description it is the strategic information which provides the basis for the perception of pieces or configurations of pieces and which subsequently determines the organisation of information encoded.

Linhares (2005) summarised his hypothesis thus ' Chunks are created when a set of abstract roles are perceived to be played by the relevant piece, groups of pieces, or squares. These abstract roles emerge from subtly perceived pressures in many levels such as pieces; key squares; piece mobility; and attack, defense, and distance relations...and their perception leads to a strategic vision of a position'(p 175).

5.2.2.3 Validation of the Abstract Role Concept

In a later paper, Linhares and his fellow researcher (Linhares & Brum, 2007) explained how two chess boards containing a different number of pieces, different sets of pieces and pieces in different positions on the board, could nevertheless have high strategic similarity. In figure 4.1 white has been check-mated by the Queen in the board A and the bishop in board B. While the game has barely begun, and all pieces are still in play on board A, only five pieces remain on board B. Yet the nature of the entrapment of the King is identical in both examples and therefore provides an almost identical strategic scenario. The authors suggested that very experienced players would use their 'strategic vision' rather than pattern recognition to encode and recall these positions.

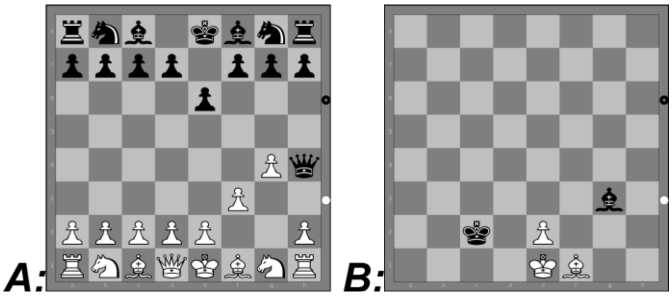


Figure 5.1 Strategically similar but visually dissimilar board configurations (From Linhares & Brum 2007)

To evaluate their theory, Linhares and his colleague tested a group of expert (Class A & B) chess players against a novice group. Participants compared 20 photographs of chess positions in which ten were highly similar in terms of the positions of pieces on the squares and ten were dissimilar board layouts but having similarities in the abstract roles played by some of the pieces.

Although both groups were instructed to find pairings for each position using the criteria of 'essence not appearance' and to 'look for similarities of strategic vision' (p996), only the expert group consistently paired the positions by the abstract role categorisation. As a result, the expert group paired board scenarios using strategic considerations almost twice as often as the novice group.

The authors concluded that expert players do see strategic similarities when similar abstract roles are present and while position-on-square information is necessary it may not be sufficient to account for all aspects of chess expertise. It was also suggested that the novices appeared to have difficulty perceiving the abstract relations that defined the positions strategically possibly due to confusion with the surface appearance.

5.2.2.4 Pattern Recognition, Abstract Roles and Map Reading

The literature review in Chapter 2 provided considerable evidence of the important role played by pattern recognition in map reading tasks. Indeed, at a fundamental level the task of self location consists predominately of spatial feature-matching the geometric or symbolic information provided on the map with topographical feature-matching in the landscape being represented (Chang et al., 1985). Skilled map users have been shown to extract added meaning from map symbols based on the known relationships of associated features or a familiarity with the environment being represented (Montello & Freundschuh, 2005), and this was achieved primarily by efficient pattern recognition.

Within the previous chapter and in other research work on map reading tasks the verbal protocols of skilled participants have provided reliable confirmation that features are studied and encoded within a framework of recognisable patterns incorporating the spatial relationships between features (Davis, 2005; Gilhooly et al, 1988; Kent & Cheng, 2008).

So while pattern recognition is a familiar research theme in map reading, the concept of the abstract roles of studied features and how knowledge of them might contribute to map reading skills has yet to be addressed. Theories of expertise have identified the importance of developing domain knowledge, cognitive skills and decision strategies to address the task characteristics (Shanteau, 1992). However, the task characteristics associated with map reading are diverse and as already noted encompass many disciplines such as analysis of GIS data (Audet & Abegg, 1996), decision making in urban planning (Bordogna et al., 2006) and cognitive mapping to assist in search tasks (Gibson, 2001).

Yet across the domains the common requirement in map usage is to extract information and meaning from the map display. In the most demanding tasks it is possible that the ability to extract meaningful information might be enhanced by the user-knowledge of the functionality as well as the spatial relationship of features within a location.

For instance, a topographical map might portray features such as a reservoir, a dam, an adjoining valley and a Hydro-Electric station. These features could exist within a number of spatial configurations but by virtue of their abstract roles they also exist within a functional relationship governed by relative altitude. The Hydro-Electric station cannot be higher than the reservoir. The dam cannot be lower than the reservoir and all three must be higher than the valley floor. Importantly, this relationship is inviolate and as such it may provide greater facilitation for the rapid recognition and association of individual features. Knowledge of the altitude relationship, whether explicit or implicit, might influence strongly how the expert map user visualises, categorises, and encodes the group of features.

Given the importance of feature functionality as an aid to comprehension in skilled map reading it is surprising to discover that there are no studies that have specifically researched this topic. It may be that pattern recognition is a more intuitive explanation of how experts might process map data. Indeed pattern recognition is quite clearly the key to successful map comprehension in many tasks. Possibly, the abstract roles of features, while relevant to chess expertise, may have importance only in the more advanced map reading tasks and then may be employed only by the most skilled map users. Also, the use of abstract roles by experts might incorporate knowledge acquired over many years and which through familiarity or constant use eventually evolves into implicit rather than explicit cognitive processing. In this case experienced map users might well be unaware of the contribution to overall comprehension provided by their knowledge of the functionality of individual features.

The most probable reason for the lack of research into abstract roles and map comprehension is, however, the difficulty of the endeavour. Where Linhares & Brum identified a design which appeared to successfully separate the functional and perceptual similarities of chess configurations, identifying a research design to demonstrate how skilled map readers separate the functional or strategic relationships of features from their spatial relationships during the encoding of map data is more challenging.

This study nevertheless attempts to examine this previously neglected area of map-reading research within an experimental design described in the following sections.

5.2.3 Characteristics of the research design

The factors that influenced the selection of an experimental design to address the three research questions are now considered.

The first research question '*Do expert map readers employ cognitive schemas such as templates when engaged in a map comprehension task?'* had been addressed by the first experiment reported in Chapter 3 and in earlier studies. However the second and third research questions for this study are only relevant if participants' use of cognitive schemas or templates can be identified during completion of the experimental task. The design therefore had a requirement to demonstrate at the outset, that the participants were employing these information processing strategies.

The second research question was *'Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping features according to familiar patterns?* This question had been partially answered in earlier studies but it had not been confirmed that pattern recognition was a sufficient description of how experienced map readers had encoded information. Importantly, this question had not been previously researched with expert contour map users engaged in a planned experimental task with high external validity.

The third research question was *'Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping features according to abstract roles?* This question had not been previously addressed and posed the greatest problem. The abstract roles of features portrayed on a map are not as clearly delineated as those possessed by pieces on a chess board. Nor are the roles of geographic features universally perceived in an identical fashion among expert map users. Importantly, even if it can be shown that the expert map users do not exclusively employ pattern matching when studying contour map data, it would still be necessary to demonstrate that they were employing abstract concepts instead.

The experimental design employed by Linhares & Brum (2007) provided expert chess players with a familiar task in which the participants had to choose between visual congruence and strategic congruence in an evaluation of board similarity. Despite the instructions to participants to concentrate on the similarities in strategic vision, half the novice group selected the boards most similar by pattern recognition.

It was considered that the second and third research questions for the current study might be addressed with a design incorporating a similar task of matching map locations by their similarity either visually or strategically. The task characteristics would require careful modification to produce an exercise with external validity which both groups would find demanding but not impossible to achieve. Liaison with Ordnance Survey provided confirmation that the proposed task would have high ecological validity for the Expert group of field surveyors. In addition, the results might contribute to current studies which research the concept of place and the features which define the outer extent of places.

As in the previous study, verbal protocols could provide evidence of the use of information processing strategies in response to the first research question.

5.2.4 Selection of the experimental research design

This section provides justification for selecting an experimental design loosely based on the Linhares & Brum study and the rationale for the modifications incorporated to adapt the earlier design for a map study task.

5.2.4.1 The Linhares & Brum Experimental Design

A group of 22 experienced (all above 1600 ELO rating) chess players were tested against a group of novice players. Participants were presented with 20 pictures of board configurations containing distributions of chess pieces from a variety of unrelated games.

Their instructions were to select 10 pairings which were similar in ‘essence not appearance’ by using ‘their feelings of how the positions might evolve strategically’. Ten of the configurations were control conditions containing pairs which were closely matched by the number of pieces present and the pattern of board layout but strategically dissimilar by virtue of the positioning of one piece. The remaining 10 positions were pairs matched by configurations of pieces performing similar abstract roles but in distinctly different spatial formations.

The experts achieved almost perfect scores matching the abstract roles pairs while the novices matched exactly half. The experts matched fewer pairs of the visually similar positions than the novices as predicted. Experts and novices completed the tasks in similar time scales.

5.2.4.2 Strengths of the Linhares & Brum Experimental Design

The Linhares & Brum experimental design had two main strengths - subtlety and simplicity.

The subtlety was achieved by testing the implicit knowledge of the participants engaged in a task which putatively tested their explicit knowledge. The simplicity of the design appeared to provide an unambiguous relationship between expertise and the type of implicit knowledge employed.

In addition, by the use of a chess task the authors had access to reliable measurements of participant expertise levels at the outset. Also the task difficulty could be finely adjusted to delineate expert from novice performance.

5.2.4.3 Weaknesses of the Linhares & Brum Experimental Design

Participants were provided choices for pairing criteria between pattern recognition and abstract roles. If, as the experts demonstrated, the preferred choice was for abstract roles then it was reasonable to assume that they correctly identified that the abstract roles contributed more to the strategic similarity of the pairs than did spatial similarities.

However, while the novices failed to make similar judgements with the same reliability, it was not clear why this was so. Did the novices not recognise the abstract roles? Or did they recognise the strategic implications of the abstract roles but were nevertheless seduced by the powerful visual similarities provided in the pattern matched control pairs? The experimental design did not make any provision to evaluate further how the novices ultimately arrived at their choices.

The debate between pattern recognition and identifying abstract roles as a method of play is generally associated with a discussion on the duration of time available for board study. Briefly, pattern recognition generally accompanies rapid move selection while abstract roles are associated with longer study periods of strategic considerations (Chabris & Hearst, 2003). Since the Linhares & Brum study specifically investigated the two methods of play it was surprising that no accurate timings were made either for comparisons of task type or for participant groups. The only reference to timings reported that (all) participants took approximately 20 minutes to match the positions.

5.2.4.4 Proposed Modifications to the Linhares & Brum Experimental Design

The concept of providing participants with a choice between visual similarity and the functional equivalence of features depicted in a map reading task was considered to be a more demanding prospect than that achievable within the more structured configurations of a chess board. Novice and expert participants might reasonably be expected to have knowledge of abstract concepts within a chess scenario even though they may place different emphasis on their importance. However, map-reading knowledge is less well-defined. The diversity of tasks for which maps are used would suggest an equivalent diversification in types of expertise. The challenge therefore was to identify a task which was achievable by both groups but which simultaneously tested the expertise of the more experienced group.

Competent contour map readers are capable of identifying topographical features within a landscape. The relationships between man-made features and geographic features are also readily discernable on a contour map. Geographical and man-made features which might constitute physical boundaries for a town or village are therefore identifiable by both expert and novice contour map readers alike. In addition, interpretation of the relative importance of features in their roles of defining the boundary of a location might well be dependent on the depth of comprehension achieved by the map reader.

Accordingly, where Linhares & Brum had selected the abstract roles of chess pieces within a familiar configuration as the independent variable, this study selected the abstract roles of natural and man-made features in defining the boundaries of an urban community.

The original control condition had been provided by chess configurations which were highly similar visually but not strategically so. In this study these were replaced with map locations in which features were distributed with high spatial similarities but with features which were performing differing abstract roles.

The method of comparing the chess configurations by the pairing of cards in the earlier study had provided little opportunity to study participant activity during their completion of the task. This study proposed a design with procedural differences in which the comparison task would be conducted on a monitor from which eye-tracking data could be recorded together with individual times for task completion. Verbal protocols were also to be recorded to provide evidence of the use of cognitive schemas during the map study and comparison tasks.

5.3 Method

This section outlines the method adopted for the second experiment based on the experimental design discussed above. The section begins with information on the participants followed by details of the materials used throughout the experiment. The procedure is then provided together with a detailed description of the tasks undertaken by the participants. The experimental constraints and data analysis procedures are then addressed and the chapter concludes with the results from the pilot study employed to validate the selected experimental design.

5.3.1 Participants

A total of 40 participants were recruited for the experiment and were allocated into one of two groups. Twenty participants were professional map users and formed the Expert group while the less experienced Novice group consisted of 20 highly competent, but not professional, contour map readers. All the participants were native English speakers.

The Expert group All the Expert participants were professional field surveyors employed by Ordnance Survey with extensive experience of contour map usage. They were recruited by personal e-mail communications to the managers of the regional centres requesting volunteers for the study. Expert participants were tested on site at Ordnance Survey HQ at Southampton or in one of the regional offices located in London, Guildford and Folkstone. The average age of participants in the Expert group was 46.7 (SD = 8.5). All had a minimum of 10 years experience of regular and extensive contour map usage and many had more than 20 years of employment with Ordnance Survey as field surveyors. Only three of the Expert group were female.

The Novice group Twenty participants for the Novice group were recruited by departmental e-mail and screening interview from post-graduate and undergraduate students in the Natural Geography Department at the University of Sussex. Although designated as Novices all participants were selected because they were competent contour map users who employed contour maps for the practical modules in their coursework. The group had an average age of 27 (SD = 11.8) and 15 of the 20 were female. All were volunteers and were paid £10 for participating.

5.3.2 Apparatus and materials

This section describes the experimental measures and the equipment employed for each test procedure. The rationale for each test is provided with the detailed test description.

5.3.2.1 Participant Consent Form

A participant consent form was produced as a requirement of the School of Science and Technology ethics committee.

The form contained a brief description of the purpose of the study and an outline of the procedures to be employed in the experiment. It also highlighted the voluntary nature of participation, the participants' right to withdraw and provided assurance of the confidentiality of any results. A signature from each participant confirmed their consent to participate. (See appendix 9)

5.3.2.2 Map Experience Questionnaire

A 10-item questionnaire to examine participant levels of competence and experience with both contour and non contour maps was constructed. Three of the questions were related to non-contour maps, three questioned the participants experience with contour (Landranger and Explorer series) maps and the remaining four questions probed the participants' experience with all types of maps.

Participants responded to each question by circling one of the answers provided and each answer was graded on a five-point Likeart scale. The totals provided a familiarity with maps score for each participant.

Participant scores had been used in the previous two experiments to confirm the reliability of participant allocation into either the experienced or non-experienced group. In this study all members of the expert group were acknowledged experts. The purpose of the questionnaire was therefore to confirm that the less experienced participants were competent (but not expert) map users. (See Appendices 10.1 & 10.2)

5.3.2.3 Probe Map Slides

A total of 10 UK town and village locations were selected as *probe* slides from an extensive study of the Ordnance Survey 1:50,000 Landranger series. They were drawn from the entire UK area and selected to ensure they did not represent one region for which the Experts may have had specialist knowledge and therefore unfair advantage.

The criteria for selection of eight of these were the presence of distinct and adjacent geographic or man made features which might have determined the extent of the boundaries of the urban development. The remaining two were villages having a distinct but remote feature (railway station or road-over-river bridge incorporating the village name).

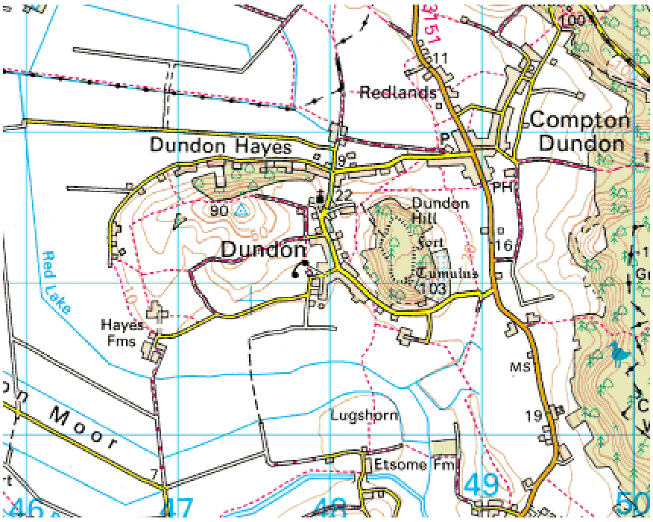


Figure 5.2 Example of village location (Dundon) with boundaries determined by geographic features

(The village is confined in a valley between two adjacent steep hills).

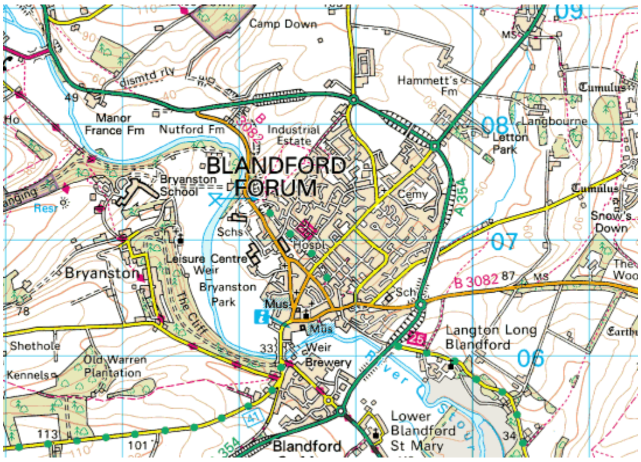


Figure 5.3 Example of Town location (Blandford Forum) with boundaries determined by geographic and man made features

(The town is surrounded by a major ring road to the East and a river valley and cliff to the West and South West)

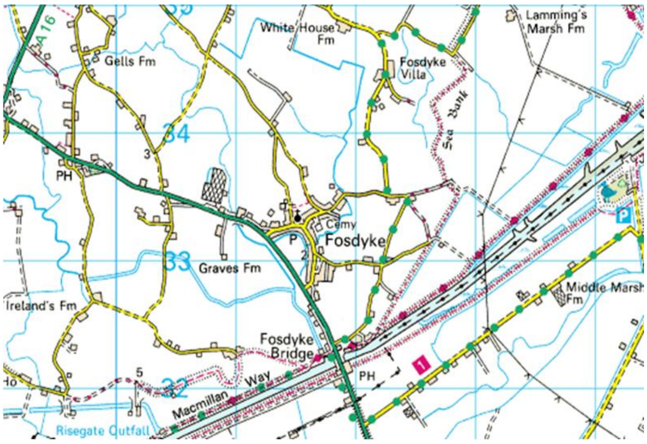


Figure 5.4 Example of village (Fosdyke) with adjacent remote feature

(The village has a named road over river bridge to the South)

Map excerpts of each location representing approximately four square Kilometres or one square mile around the town or village were produced with the location sited at the geometric centre of the map. These were scaled as JPEG images to form the *probe* slides for the map comparison task.

5.3.2.4 Combined Probe/Distractor/Target Slides

For each of the ten *probe* slides a corresponding composite slide was constructed containing a quarter size extract of the associated *probe* location sited above map extracts of two unfamiliar locations. One of these mapped locations had similarities with the probe location due to the spatial arrangement of adjacent features and constituted the *distractor* location. The remaining location portrayed a similar town or village as the *probe* location but which had boundary features performing similar abstract roles as those in the *probe* location. This map extract was the *target* location.

The combined slides were designed to provide participants with the *probe* location as a reference with which to compare the *distractor* and *target* locations during the comparison and selection for similarity task.

Figure 5.5 Combined *probe/distractor/target* slide for village (Dundon) with boundaries determined by geographic features.

(The Target location A has similar hill formations adjacent to the village which are absent in the distractor location B)

Figure 5.6 Combined *probe/ distractor/target* slide for location (Fosdyke) with remote feature

(Location A is visually similar to the probe but lacks the remote bridge present in location B)

5.3.2.5 The Experimental Task

The participants were required to study the first slide (*probe*) to identify which features determined the extent of the boundaries of the village or town located at the centre of the map extract. The second slide, presented automatically after a 15 second interval, contained the *probe* above a *distractor* (similar by feature patterns) and a *target* (similar by features performing the same abstract roles) both of which appeared in random order in either the left or right lower quadrant.

The task had been selected to test the Experts' ability to identify the functions of the features which constituted the boundaries and to examine whether the functional properties or the visual similarities of those features would be the criteria used by the Expert group to compare the similarities of each location.

5.3.2.6 Eye Tracker and Monitor.

A Tobii X120 desk monitor (1280 X 1024) eye tracker was used running at 60Hz data update with binocular tracking on a screen size of 32 x 28 centimetres. The standard fixation filter was employed throughout recording fixation times above 100ms and within a radius of 30pixels.

The associated software package was Tobii Studio™ version 1.2.30 running on a Dell Precison M2300 Laptop operating MS Windows XP Version 2002 Service Pack 3. The Dell hardware configuration met the high specifications for compatibility with the Tobii software with an Intel (R), Corel™ processor and duo CPU T7800 @ 2.60 GHz, with 2.00 Gb of RAM.

The Tobii eye tracker ran a programmed set of slides with a pre-set timing on all *probe* slides (odds) and a time interval based on participant mouse clicks on the combined *probe/distractor/target* slides (evens).

The eye tracking status panel was selected and displayed on the monitor and participants' audio and video recordings were concurrently captured by the event recorder, user-camera and external microphone.

Once the participant had completed the calibration exercise there was no physical evidence of the eye-tracking equipment and the recording of eye-tracking data was achieved entirely unobtrusively and without distracting from the experimental task.

5.3.2.7 Areas of Interest

The Tobii Studio software provided the facility to designate Areas of Interest (AoIs) on each of the map extracts and to construct a geometric shape surrounding each area.

These areas contained features which constituted geographic or man-made boundaries, the extent of urban development or remote features which might have had some influence on the extent of the location boundaries. The features within the AoIs had been pre-determined for their relevance to the experimental task of identifying location boundaries and were constructed prior to any analyses of the eye-tracking data. Eye-gaze data within each of the constructed areas were then inspected to provide details of the number of fixations (above 100 milliseconds) and the cumulative time participants attended to features within the area examined. Figure 5.7 shows Blandford Forum with designated Areas of Interest for physical features which influence the town boundaries. These include the high ground to the East and West, the cliff to the West and South West, The river and river valley to the South and West, The ring road and the polygon encompassing the extent of the urban development.

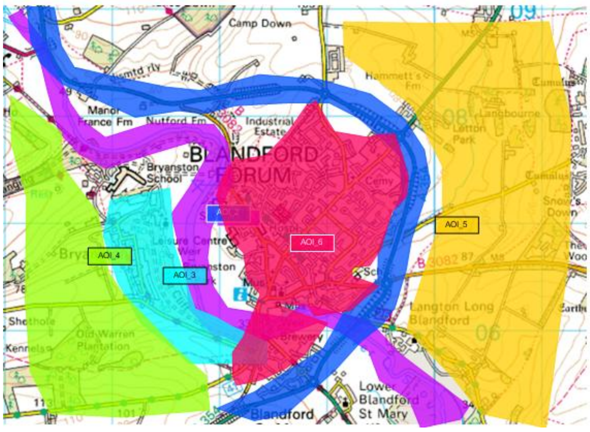


Figure 5.7 Designated Areas of Interest for a *probe* location (Blandford)

In figure 5.8 the Areas of Interest include the extent of urban development in each location, the high ground and road boundary to the North West in the *distractor* slide, the shared water features and remote bridges in the *probe* and *target* slides and the road boundary and development to the North West in the *target* location.

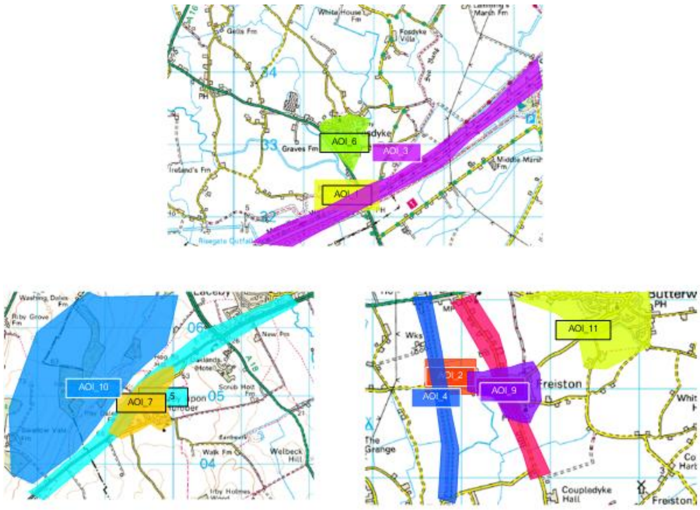


Figure 5.8 Areas of Interest for *probe/ distractor /target s*lide (Fosdyke)

The Area of Interest which enclosed the urban confines of each location was found to produce the largest group differences in eye gaze data and a sensitivity analysis for this AoI alone was conducted to determine exactly where the effect was greatest. The radius of the circled area around a selection of 10 villages and towns was subsequently varied from entirely within the urban confines to an area beyond all the urban extents. The area which appeared consistently to produce the greatest differences between the groups was however identified not as a circle but as the polygon which included the full extent of the urban development located immediately inside the identifiable location boundaries. The Areas of Interest defining the urban confines of each location were then reconfigured to match these criteria and thereby record, more accurately, eye-gaze data focussed within the extent of the urban areas.

Study times for each map extract were obtained by selecting the entire map area as an area of interest and recording the length of observation times.

5.3.2.8 Analysis of Verbal Protocols

As in the first experiment, participants' verbal protocols were obtained and recorded using the 'think aloud' technique described by Ericsson & Simon (1993). The protocols were subsequently analysed using the HyperRESEARCH™ software programme.

A total of 15 descriptions of features and location properties were identified as those which might assist participants during the boundary identification and location comparison task (See table 5.1). The codes had been selected to provide evidence of the use of either pattern recognition or the use of abstract roles during assessment of features which determined the extent of the location boundaries.

Participants' protocols were recorded on the Tobii eye tracker user-camera during the study of the *probe* map slides and again during the crucial comparisons of *probe* to *distractor* and *probe* to *target* locations in the studies of the composite slides. From the recordings all instances of code usage were highlighted in each participant's protocol and the results from the analysis examined for insights into how participants had arrived at their selection of *target* or *distractor* locations.

Code	Definiton
Independent Features	**Identifying isolated features or judging similarities of locations by reference to non-boundary features common to both**
	Eg. They've both got a church (rec 18 07.08)
Geographical Boundaries	**Identifying the role of geographical or natural features in defining the boundary of the location**
	Eg. You've got the downs either side (rec 18 07.24)
Grouping Concepts	**Association of locations by reference to shared features involving proximity or interdependency**
	Eg. Bere Regis has a small village to the SW (rec 19 01.34)
Inferring Height	**All descriptions of height related features or rate of change of height derived from use of contour data.**
	Eg. Ashingon is a generally a flatter area (rec 19 04.58)
Location Orientation	**Using cardinal points or up down left right descriptions.**
	Eg. It's a long North/South village (rec 18 00.40)
Location Shape	**Describing urban layout according to a defined shape or configuration within external features**
	Eg. It's a more rounded shape(rec 18 02.14)
Location Size	**Description of location size or inference by description ie. Hamlet, town or village.**
	Eg. Long Bennington is larger(rec 11 00.40)
Pattern Matching	**Using patterns of features ie. roads or rivers as primary method of location comparison.**
	Eg. It's a very similar shape with the bypass going round it (rec 08 11.16)
Railway	**Reference to railway lines tracks or stations.**
	Eg It's on a railway line (rec 08 09.11)
River	**Descriptions of rivers or man made water features.**
	Eg. It's on a bend in the river (rec 08 10.56)
Road	**All descriptions of roads as they define the extent, shape or infrastructure of the location**
	Eg. It's got a main road near it.(rec 08 12.47)
Relational Encoding	**Defining features or locations in relation to adjacent features or locations**
	Eg. Smack in the middle of a busy crossroads (rec 12 2.50)
Remote Features	**Identifying remote features which may be relevant in defining the extent of boundaries**
	Eg. B which also has some sort of canal (rec 39 05.11)
Specialist Schemas	**Incorporating specialist knowledge within descriptions or relationships of features**
	And a county boundary which would be seen as the edge (rec 18 06.06)
Urban Density	**Reference to density or extent of built up areas within studied location**
	Eg. Just one or two houses (rec 37 06.01)

Table 5.1: Protocol codes capturing feature and location descriptions in the map study and location comparison tasks.

5.3.3 Procedure

5.3.3.1 Overview of Procedure

All the Expert participants were tested at their place of work in the Ordnance Survey HQ or at one of the regional offices. In each location a workstation area was provided in which the portable Eye-tracker, monitor, and Dell laptop computer could be rigged and operated.

The Novice participants were tested at a dedicated workstation in a laboratory attached to the Representation and Cognition Research Group, University of Sussex.

All participants were tested individually and began by completing the participant consent form and the map experience questionnaire.

The participants were then asked to study the written instructions presented on the screen and to ask any questions if they were unsure of the task. After which they were required to study extracts of maps presented on the eye tracking monitor and subsequently to match the initial location with one of two alternatives presented on a composite slide. The experimental task instructions stated that participants were to select the location most similar in terms of the features which determined the extent of its boundaries. After completing a practice run, during which they could ask any questions the participants repeated the exercise for the 10 separate pairs of location slides.

Participants provided a commentary of their thought processes during the study of the *probe* location and the subsequent composite slide.

5.3.3.2 Detailed Sequence of Testing

Participants were seated at the workstation throughout the 35 minute experiment and completed the following procedures in sequence. The experimenter was seated well clear on the left hand side with a laptop presentation of the monitor screen, the eye-tracking status panel and a reduced window indicating the user-camera display.

- **Participant consent form** At the outset all participants were asked to read a brief description of the experiment, a statement about the voluntary nature of their attendance and to ask any questions if they wished. They then provided a signature to confirm their willingness to participate.

- **Map experience questionnaire** Participants were presented with a questionnaire which recorded their candidate number, sex, age (optional) and 10 multiple-choice questions which examined their experience levels for a number of different map reading tasks. They responded to each question by circling their chosen answers.

- **Initial eye-tracker calibration** Each participant was asked to adopt a comfortable viewing position at a viewing distance of approximately 70 centimetres from the screen. The monitor was tilted until the eye tracking sensors were indicating successful tracking status for each eye as represented on the supervisors display. The calibration sequence was initiated during which the participant focused on the moving stimulus. Successful calibration was almost invariably achieved after one run.

- **Practice task.** A practice task was completed to familiarise each participant with the procedure for the experiment and to confirm that the eye-tracking sensors were recording satisfactorily. When each participant was ready they were asked to click on the 'start recording' button on their monitors and to read the instructions which would then appear. These stated:

'You are about to view an excerpt taken from an Ordnance Survey 1:50,000 map. In the centre of the picture is a town or village. You are asked to study this location for 15 seconds after which the screen will change to a slide containing a smaller picture of the location you have just studied above two pictures of different locations.

After comparing the two pictures with the reference location please select the picture, either A or B which in your opinion is most similar to the reference location in terms of the features which might determine the extent of its boundaries. Please use the mouse to indicate your choice with a left-click for picture A and a right-click for picture B.

You are asked to 'think aloud' as you study each of the pictures by providing a commentary of what you are noticing about each location and which features you are considering during your comparisons and decision making.'

When the participants had been asked if they had any questions and were ready to continue they were instructed to click the mouse after which the *probe* picture appeared for 15 seconds (Figure 5.9). This was followed automatically by the *probe/distractor/target* slide (Figure 5.10).

Figure 5.9 Practice task *probe* slide (Whitehaven)

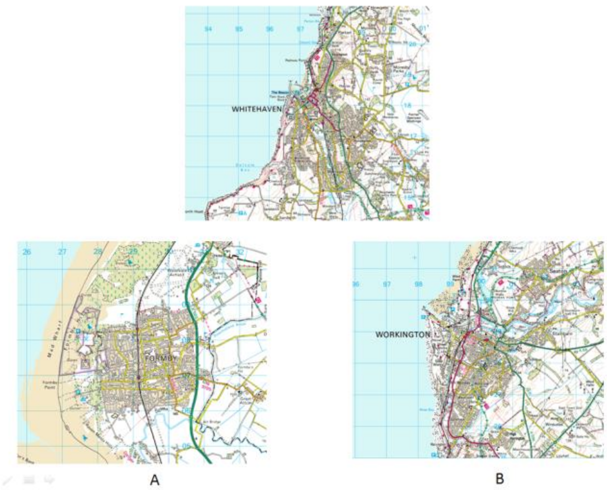


Figure 5.10 Practice task *probe/distractor/target* slide

- **Main experimental task.** After completing the practice task, participants were again asked if they had any questions and if necessary were reminded to 'think aloud' while studying the maps and making their selections.
  The experimental test was then selected on the Tobii software and the recording commenced with a standard calibration and a display of the instructions previously presented for the practice task but which now included:

  The next location will then appear automatically for the 15 second study period. This procedure will be repeated for 10 separate locations.

Participants then studied the *probe* slides for the pre-determined 15 second viewing and then studied the composite slides. When they had made their decision of similarity between either the *target* or *distractor* location they completed the procedure with a left or right mouse click corresponding to their choice. All 10 pairs of slides were completed without interruption and with participants providing verbal commentaries throughout.

On completion, all participants were thanked and retained for the second part of the experiment reported separately in the following chapter.

5.3.4 Experimental design considerations

5.3.4.1 Experimental Constraints

Participant numbers were determined by the number of Expert map users who could be recruited for the experiment. Twenty field surveyors did not constitute the full complement of surveyors available at Ordnance Survey but did represent a reasonable group size when geographic and time constraints were considered. It is relevant that there are no comparable studies in the literature in which the level of map reading expertise had been so highly concentrated within one Expert group for a comprehensive examination of expertise.

The number of Novices required was dictated simply by the number of Experts. However, recruitment of 20 competent, but not expert, contour map readers still necessitated careful screening. For practical reasons, the Physical Geography Department at the University of Sussex was selected as the recruitment area but the drawback was that the majority of recruits were female and younger than the Experts. As a result, it had not been possible to control fully for gender and age effects across the groups.

The length of the experiment was determined by participant availability and the decision to conduct a further study with the participants on completion of the first task. For this reason the number of location stimuli used for the comparison study was limited to 10 pairs.

5.3.4.2 Methodological Considerations

The requirement to evaluate the cognitive strategies employed by expert map users to process map information posed a demanding problem. Eye tracking alone might have provided valuable clues as to which feature was being attended to but it might not have explained why the feature was significant in the decision making process. Also, the purpose of the experiment had been to identify whether the experts might judge the abstract roles of features rather than the pattern of their layout as the most relevant factor in their processing of data. This would not be clear from data from eye movements alone. As a result, a combination of eye tracking and protocol analysis was selected.

The experimental task was designed to engage all participants in an exercise which apparently tested their explicit knowledge of what constitutes the boundary of an urban development. In fact it was largely testing their implicit knowledge of the physical relationships between the studied features. The task of judging similarities between the *probe,* the *target* and the *distractor* locations was again designed to draw on implicit as well as explicit knowledge. The task was therefore one in which expert implicit knowledge might be demonstrated to provide a more comprehensive understanding of the abstract functions fulfilled by features.

The Tobii X120 eye tracker did not have accuracy levels or update rates to match some of the more sophisticated models but at 60 Hz tracking frequency and 100 ms sensitivity was suited to the task of recording search patterns on a static stimulus presented on the monitor. However, it had the advantage of being totally unobtrusive in use, thereby contributing to the internal validity of the experiment. Additionally the equipment was fully portable and this had been a requirement for testing most of the Expert participants at remote field offices.

The use of HyperRESEARCH™ software to analyse the verbal protocols had been employed satisfactorily for the earlier experiment and therefore was again selected for this experimental measurement.

5.3.4.3 Data Analysis Procedures

To evaluate group differences for a wide variety of measures, statistical analysis of a large number of separate dependent variables was necessary. The use of t-tests on every variable was therefore unsafe due to the risk of inflating the family-wise error rate and increasing the chance of introducing type 1 errors (Field, 2000)

However, since the variables relating to group differences on the main experimental measures of 'Experience with maps questionnaires', accuracy scores and study times were independent and not repeated measures these were examined by univariate analysis of variance (ANOVA). This was considered reliable within the following four assumptions for this analysis:

- **Independence**. All observations were statistically independent.
- **Random sampling**. Participants in each group were random samples of their populations.
- **Univariate normality**. The dependent variables were considered to have univariate normality within groups.
- **Homogeneity of variance**. The variance in each group was assumed to be equal.

The first two assumptions were addressed by the experimental design. The third assumption required normal distribution of data within the two groups. Confirmation of this assumption was not possible using SPSS in a univariate analysis. However, when group sizes are balanced, as they were in this experiment, Field (2000) advises that multiple comparisons still perform well under small deviations from normal distributions. Howell (1997) confirms this view by claiming that ANOVA is a robust statistical procedure and normality assumptions in particular can be violated with relatively minor effects.

The Homogeneity of variance assumption was validated with a Levine's test. On all the main tests the Levine statistic was non-significant indicating that this assumption had not been violated. All ANOVA reports in the results section give the significance and F values for the univariate analyses conducted and all results give the significance for a two-tailed test except where stated.

Statistics from the eye-tracking data for fixation counts and fixation lengths were also separately analysed by ANOVA. In some cases the data provided low numerical values due to low activity levels within the Areas of Interest. As a result, the Homogeneity of variance assumption was occasionally violated. Where the Levine's test was significant each of the relevant tests was independently examined using a t-test with a more stringent analysis for groups with non-equal variance. Where appropriate the revised significance value was reported.

Despite the use of between five and 15 AoIs on each slide the significant differences with p values below .05 and .01 were reported without Bonnferoni corrections. If these results had reported main experimental effects then values close to significance would have been considered unreliable. However as they reported differences in group search activity within each slide they provided cumulative evidence to support the expert group's greater attention overall to geographical and physical features. These non-corrected results are therefore reported but with the added caution regarding their reliability.

Similarly, examination of the protocol analysis revealed that a total of 14 codes were examined by ANOVA. These results, however, reported a main experimental effect and all were therefore subjected to Bonnferoni correction. As a result, three codes were no longer reliably significant and were reported accordingly.

5.3.5 Pilot study

A pilot study was conducted prior to running the experiment to assess the design and to confirm the anticipated experimental timings.

5.3.5.1 Pilot Study Procedure

One skilled map reader and one novice participant were selected to validate the experimental design. Both participants were Post-graduate students attached to the Representation and Cognition laboratory at the University of Sussex.

As fellow researchers, their abilities with contour maps were already known and they did not complete the ‘Experience with maps’ questionnaire. Similarly there was no requirement for a participant consent form.

Both participants read and understood the instructions and had no difficulties with the task requirements. Both the skilled map reader and the novice favoured the *distractor* location on almost all their selected answers, thereby confirming that they were arriving at their solutions by pattern matching. Both participants were observed studying the *probe* location during the timed 15 second interval and appeared to have completed their inspection when the composite slide appeared.

The skilled participant chose the *target* location for one of the two remote feature locations (Fosdyke) in which a remote bridge was the feature common to both. However, in the verbal protocol, it was evident that this was based on the presence of a water boundary rather than a match of the remote features. Overall both participants were seen to be making non-random choices based on pattern recognition principles without considering the abstract roles of the features. This result had been predicted by their levels of experience with map reading tasks and confirmed the validity of the experimental task in providing *probe* and *distractor* solutions with high visual similarity. It did not prove, however, that the abstract roles in the *target* slides would be identifiable to the experts. This element of the procedure could only be reliably answered by completing the formal experiment.

The novice map reader was an enthusiastic volunteer and this resulted in animated head movements toward and away from the screen during the study of the map extracts. This caused the eye tracker to occasionally break lock and provided incomplete tracking data.

5.3.5.2 Changes Resulting from the Pilot Study

The task instructions and comparison tasks appeared to be readily mastered by both trial participants and the *probe* study timings were sufficient for the initial inspection. No changes were deemed necessary to the experimental procedures.

As a result of the observed problems maintaining lock with the eye tracker when participants made excessive head movements, a slide was produced (Figure 5.11) to be integrated in the set of location slides to appear at the beginning of the sequence.

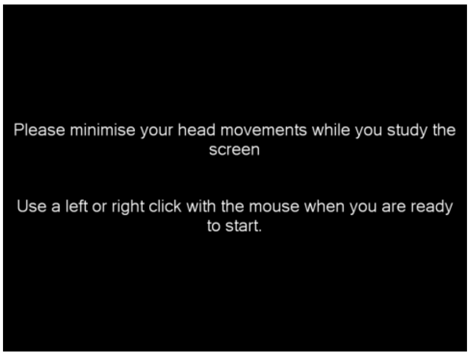


Figure 5.11 Instruction slide introduced after the pilot study

5.4 Results

5.4.1 Experience with maps questionnaire.

Experimental instrument: Ten item questionnaire Comparison of scores from the completed 'Experience with maps' questionnaires confirmed, unsurprisingly, that the experienced group were more frequent users of Ordnance Survey maps and more familiar with maps generally than the Novice group. Self-report measures for the Experts (M = 39.4 SD = 4.1) were significantly higher than Novices (M=32.3 SD=4.8) when examined by ANOVA, $F(1, 38) = 25.5$, $p < .01$.

5.4.2 Boundaries comparison task and study times

Experimental instruments: Eye-tracking data and user-camera recordings Participants had been instructed to study each *probe* location in turn and to compare it with the associated *target* or *distractor* locations in the composite slide for similarities of the location boundaries. The number of correct selections of *target* locations had been obtained from data produced in the event recorder for each participant and group means compared.

The Expert group accurately judged that the boundaries in the 10 *probe* locations matched the boundaries in the *target* locations significantly more often (M = 5.5 SD = 1.2) than the Novice group (M = 4.5 SD = 1.8), F (1, 38) = 4.13, p < .05.

This result supported the main experimental hypothesis that the Expert group had placed greater reliance on the abstract roles of features rather than their visual similarities during the boundaries comparison task.

Study times. All *probe* slides were pre-programmed to display for 15 seconds but the associated *probe/distractor/target* slides were studied until each participant selected either the *target* or *distractor* slide by a left or right click on the mouse. Since the experts had differed in how they processed the map information it had been expected that they would have differed in the time taken to process the map data by taking less time to complete the task of comparing the *probe* location with the *distractor* and *target* locations. However, this was not confirmed.

Measurement of study times for each of the *probe/distractor/target* slides showed that Experts took longer (M = 39.8 seconds, SD = 20.8) than the Novices (M = 30.3 seconds, SD = 15.3) to make their selection but the difference was not significant.

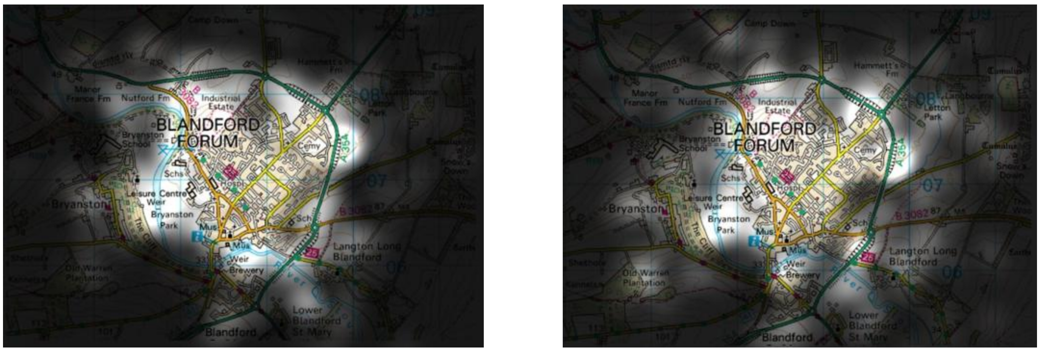
Study patterns for probe slides The groups differed in their patterns of studying the *probe* slides during the 15 second viewing. On measurements of observation length within the pre-defined Areas of Interest, Experts spent significantly longer (M = 6.6 SD = 13.9) focused within the urban confines of the location than the Novices (M = 5.1 SD = 1.8), F(1, 38) = 8.18, p < .01 (Table 5.2).

	Urban Area- group study times		**Sig**
	Experts Mean (SD)	**Novices** Mean (SD)	
Study Time in seconds	6.6 (1.4)	5.1 (1.8)	**
Percentage of 15 sec study interval	43.8 (9.3)	34.2 (11.8)	**

**Significant at the .01 level

Table 5.2 *Probe* Slides - Group Study Times for Urban Areas.

This result could be further demonstrated by comparing group study times in a gaze-opacity plot. In Figure 5.8, areas which have been studied for the longest period are shown as the least opaque. The Expert group study patterns can be seen to differ from the Novices in that a higher percentage of study time has been dedicated to the populated area of the town and the immediate boundaries. Novices appeared to spend proportionately longer attending to features further displaced from the urban centre.



Expert study pattern **Novice study pattern**

Figure 5.12 Group differences in study patterns of urban areas in *probe* slides

Study patterns for probe/distractor/target slides. When studying the composite *probe/distractor/target* slides, the Expert group spent a significantly longer period (M = 4.9 SD = 3.8) returning to and observing the urban confines of the reproduced probe picture than the Novices (M = 2.9 SD = 1.9), $F(1, 38) = 4.7$, $p < .05$. However, since the two groups differed in the length of study times a more meaningful comparison of study patterns was obtained by examining the percentages of time spent studying the urban confines.

This comparison showed that participants employed a similar pattern of cross referencing between *probe*, *target* and *distractor* locations. Each group spent approximately half their chosen study time studying the built-up areas of the presented locations with the percentage times for the Novices (M = 45.5 SD = 13.7) closely matching those of the Experts (M = 46.3 SD = 11.3) and not differing significantly in the percentage of time spent observing the built-up areas of all three locations (Table 5.3).

Location Map	**Urban Areas group study times – Percentages**		Sig
	Experts –Mean (SD)	**Novices** – Mean (SD)	
Probe	11.4 (4.2)	9.4 (3.7)	-
Target	16.8(5.5)	16.8 (5.5)	-
Distractor	18.2 (5.3)	19.3 (6.4)	-
Totals	46.4 (11.3)	45.5(13.7)	-

Table 5.3 *Probe/distractor/target* slides - Group study times (percentages) for Urban Areas

Study times for the combined *probe/distractor/target* slides were examined to establish patterns of activity during the selection of the *target* location. Participants from both groups consistently divided their attention between the *probe* and the paired *target* and *distractor* locations at a ratio of approximately 1:3.

Again, because the mean study times for each group were not equal, the times for studying the *probe* location were obtained by comparing the time actively studying each location map extract compared to the overall study times and expressing this as a percentage. Time spent by the Experts revisiting the picture of the *probe* location was 24% (M = 23.9 SD = 7.1) which was not significantly different from the novices at 23% (M = 22.7 SD = 6.9).

Participants therefore studied the *target* and *distractor* locations for approximately three quarters of the overall study times with Experts (M = 76.0 SD = 7.1) not differing significantly from Novices (M = 77.3 SD = 6.9).

Slide	Map location	AoI	AoI Description	Expert		Novice	
1	Probe (Large)	2	River boundary SW	5.6	*	3.8	
		3	Urban Confines	28.1	*	23.3	
		6	Wooded Area to East	2.9		9.2	**
2	Distractor	2	Open area between UC and river	9.9	*	5.1	
	Target	10	River	10.6	**	4.8	
	Distractor	12	River	9.1	*	3.5	
3	Probe (Large)	-	-				
4	Probe	8	Urban Confines	14.2	*	7.1	
	Target	9	Urban Confines	20.0	*	11.8	
5	Probe (Large)	1	Hill boundary to East	8.3	*	5.1	
		3	Urban Confines	8.1	*	5.8	
6	Target	2	Hill boundary to North	9.1	*	5.2	
7		-	-				
8	Distractor	3	A road boundary to East	10.0	*	6.6	
	Probe	5	Hill boundary to North	11.1 s	+	4.8 s	
9	Probe (Large)	2	Railway (Part of Remote feature)	.1		1.0	*
		8	A road to South (non boundary)	.45		1.65	*
10	Probe	1	Rail Station (Remote Feature)	.45	*	0	
	Probe	6	Urban Confines	10.4 s	+	5.2 s	
11	Probe (Large)	2	Hill Boundary to West	3.1		6.7	**
		3	A road boundary to South	1.9		3.8	*
		4	River through town	6.2	*	3.7	
12	Distractor	7	River through town	16.3	*	10.3	
	Probe	8	River through town	8.0	*	4.9	
13	Probe (Large)	7	Rail line Boundary	4.2		6.3	*
14		-	-				
15	Probe (Large)	1	River Boundary	6.9	*	4.8	
		4	High Ground to West	.75		1.7	*
		5	Hill Boundary to East	1.8		4.2	*
16		-	-				
17	Probe (Large)	2	Canal (Part of remote feature)	5.1		9.2	*
18	Distractor	5	A road	8.7	*	4.7	
	Distractor	10	High ground to West	8.1	*	3.4	
19	Probe (Large)	2	High Ground to West	2.8		5.3	*
		6	Hill boundary to South West	.35		1.8	*
20	Target	4	Hill Boundary to NW	9.2	**	4.4	
	Target	8	Urban Confines	6.8	*	3.5	

Fixation counts (number) significant at the .05/.01 level */**.
Observation length (Secs) significant at the .05/.01 level +/++

Table 5.4 Group differences for fixation counts and obsevation lengths within designated Areas of Interest

Fixation counts & gaze durations within designated AoIs (all slides) Eye-gaze data for each participant was evaluated by measuring fixation counts (number of fixations above 100ms within a 30 pixel radius) and observation length (cumulative time in seconds) within each designated Area of Interest. Group means for each measurement were then compared. Groups with significantly higher scores for either of the two measurements were reported in Table 5.4.

The eye-gaze data confirmed that the Expert group had directed more of their attention than the Novices, either with longer study times or higher number of fixations, on to geographical and physical features. These features included adjacent rivers and hills and for these features the Experts had significantly higher attentional scores for 13 of the features. These slides with associated AoIs in brackets were 1(2), 2(10), 2(12), 5(1), 5(2), 8(3), 8(5), 11(2), 11(4), 12(7), 12(8), 15(1), 20(4). This compared to the five recorded by the Novices in slides 11(2), 11(3), 13(7), 15(5), 19(6). On four occasions Novices had higher scores than Experts for non-boundary features such as woods, canals and railways 1(6), 9(8), 15(4), 19(2).

Earlier analysis had shown that the Expert group had significantly longer observations within the urban confines of all the *probe* location slides and this study pattern was also evident in four of the locations presented in the 10 combined *probe/distractor/target* slides 4(8), 4(9), 10(6), 20(8).

Two *probe* slides, 9 & 17, contained remote features. Slide 9 (Cowden) and its associated slide 10 contained remote railway stations in the *probe* and *target* locations. Both stations were annotated with the adjacent village name and might therefore have been considered to constitute the outer extent of the village boundary. Although the Novice group recorded higher fixation scores than Experts on the railway feature, the groups did not differ in their attention to the rail station itself. In the composite slide, however the Expert group studied the rail station in the *probe* location with a higher number of fixations than Novices.

Similarly, slide 17 (Fosdyke) and its associated slide 18 contained villages adjacent to a canal in the *probe* and *target* locations with a road/river bridge sharing the name of the village constituting the remote feature. In the *probe* slide the Novice group scored higher fixations than Experts along the length of the canal but not specifically on the bridge feature. No group differences for the remote features were recorded in the associated *probe/distractor/target* in slide 18.

Interestingly the groups had identical scores for selecting the *target* slide for the two remote feature slides. For the remote station in Cowden both groups largely failed to assess the station as constituting a possibly similar boundary feature and only six out of 20 participants in each group selected it.

For the remote bridge at Fosdyke, which contained a similar feature in the *target* location, 14 participants in each group selected the correct slide. From the eye-tracking data it had not been possible to identify any group differences in the assessment of the remote bridge as the boundary. More likely it had been the presence of the canal within the probe and target slide which had assisted the predominately correct decision making by both groups.

5.4.3 Feature description and integration during map study

Experimental instrument: Analysis of participants verbal protocols Analysis of each participant's protocol using the HyperRESEARCH™ software provided measurements of the number of occasions the recorded commentary contained words or phrases which matched the descriptions for the codes outlined in Table 5.1. The groups differed significantly in their use of six of the 14 codes with the Expert group recording significantly higher use of codes relating to *Geographical Boundaries, Inferring Height, Location Orientation, Reference to Roads* and *Use of Specialist Schemas*. The Novice group recorded significantly higher use of the code for *Independent Features* than the Expert group (Table 5.5).

The groups did not differ significantly in the number of instances the remaining codes were recorded in their protocols.

Code	Instances of code usage		Sig
	Expert Group mean (SD)	**Novice Group** mean (SD)	
Geographical Boundaries	10.3(6.8)	2.1(1.9)	**(**)
Independent Features	.35(.59)	3.5(3.2)	**(**)
Inferring Height	16.0(11.3)	7.7(5.7)	**
Specialist Schema	3.2(3.1)	.3(.6)	**(**)
Location Orientation	1.25(1.7)	.1(.3)	**
Location Size	4.4(3.3)	4.1(2.5)	
Pattern Matching	2.6(3.7)	2.1(1.6)	
Location Shape	6.6(5.1)	5.0(5.6)	
Urban Density	3.7(4.1)	4.4(3.0)	
Road	20.4(8.2)	14.9(5.7)	*
River	10.7(6.5)	7.8(4.4)	
Railway	2.9(2.0)	2.6(1.3)	
Remote Features	.6(1.0)	.45(.76)	
Grouping Concepts	.25(.56)	.05(.22)	

**Significant at the .01 level / *Significant at the .05 level / (**) Significant at the .01 level after bonnferoni correction

Table 5.5 Group Means for frequency of code usage during verbal protocols

The employment of 14 individual codes had, however, introduced the risk of Type 1 errors and in order to minimise this possibility all the results were re-examined applying a bonnferoni correction. Group means for three codes remained significantly different after correction: *Geographical Boundaries; Independent Features*; and *Specialist Schemas*.

Geographical Boundaries: The definition of this code included the requirement to both identify a specific geographical feature and to identify that it constituted a boundary of the town or village. Thus, protocol which included descriptions similar to:

'Bounded by the river' (rec 24, 05.11), or '*on the edge of the South Downs' (rec 16, 03.04)* qualified, while descriptions simply identifying a geographical feature such as *'Beckington has a road and river' (rec25, 00.44)* and *'B has a river and a rail' (rec30 05.57)* were not included. (Protocols are referenced by the recording number followed by the elapsed recording time in minutes and seconds).

Experts averaged just over ten (M = 10.3, SD = 6.8) instances of identifying the role of *Geographical Features* as boundaries compared to the Novices (M = 2 .1, SD = 1.9), F(1,38) = 27.3, p <.01, (See Figure 5.13).

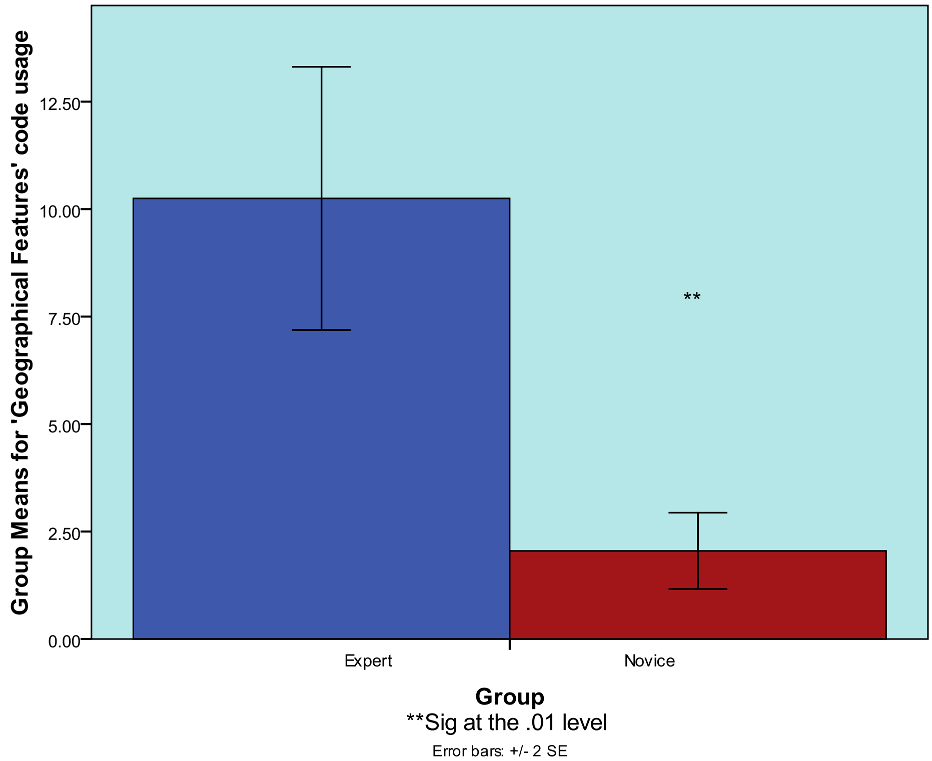


Figure 5.13 Group means for protocol code '*Geographical Boundaries*'

Independent Features: This code defined the procedure of identifying specific features on the maps which did not relate to boundaries but which may have affected judgements of location similarities when present in two or more of the locations in the composite slides. Descriptions such as:

'to the right there is a wooded area'(rec 46,01.24) and '*Cissbury ring is on the right hand side' (rec 45, 04.14)* were included in this classification.

The Novice group averaged significantly more (M = 3.5 SD = 3.2) instances of these feature descriptions than the Expert group (M = .35 SD = .59), F(1,38) = 17.9, p<.01, (Figure 5.14).

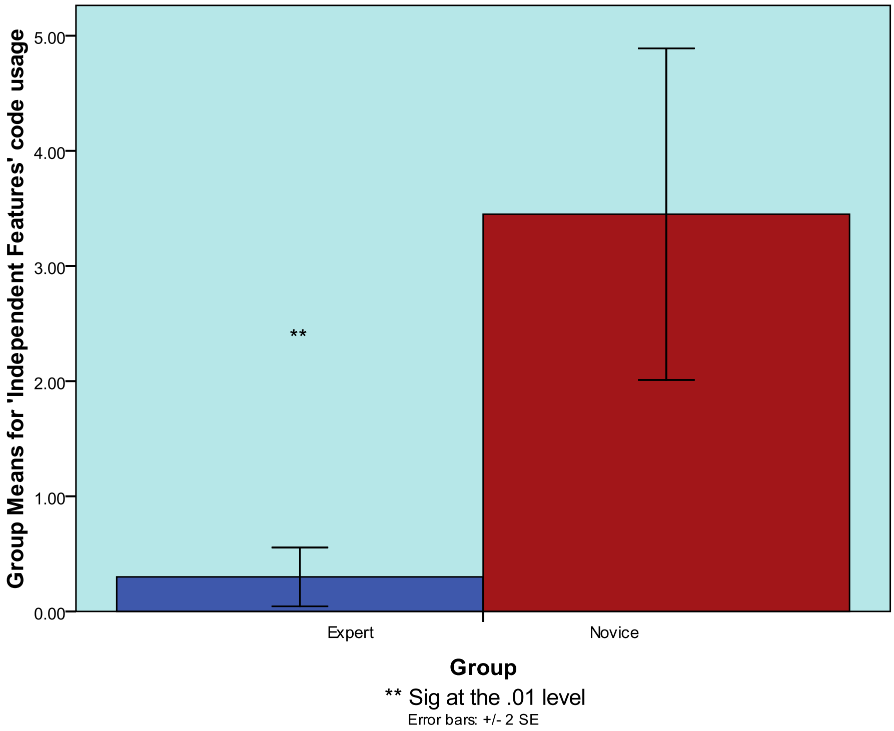


Figure 5.14 Group means for protocol code '*Independent Features*'

Specialist Schemas: This code was employed to capture evidence of the use of specialist knowledge during map study and interpretation. As participants from both groups were competent map readers, the code for *Specialist Schemas* was not employed for examples of merely identifying advanced map symbols but instead was used when the studied map information was incorporated into existing knowledge to generate a more comprehensive understanding of the location and it's boundaries. Examples included:

'*and a county boundary which would definitely be seen as the edge' (rec 18 06.06)*, or '*there is a National Trust area to the East so there might be a big house which is causing the boundary on the Eastern side' (rec 27 04.39)* and *'it's on a very flat area with a risk of flooding which is why they have positioned the village between the hills' (rec 27 03.16).*

The Expert group employed *Specialist Schemas* significantly more often (M = 3.2 SD = 3.1) than the Novice group (M = .3 SD = .6), $F(1,38) = 16.2$, $p < .01$, (Figure 5.15).

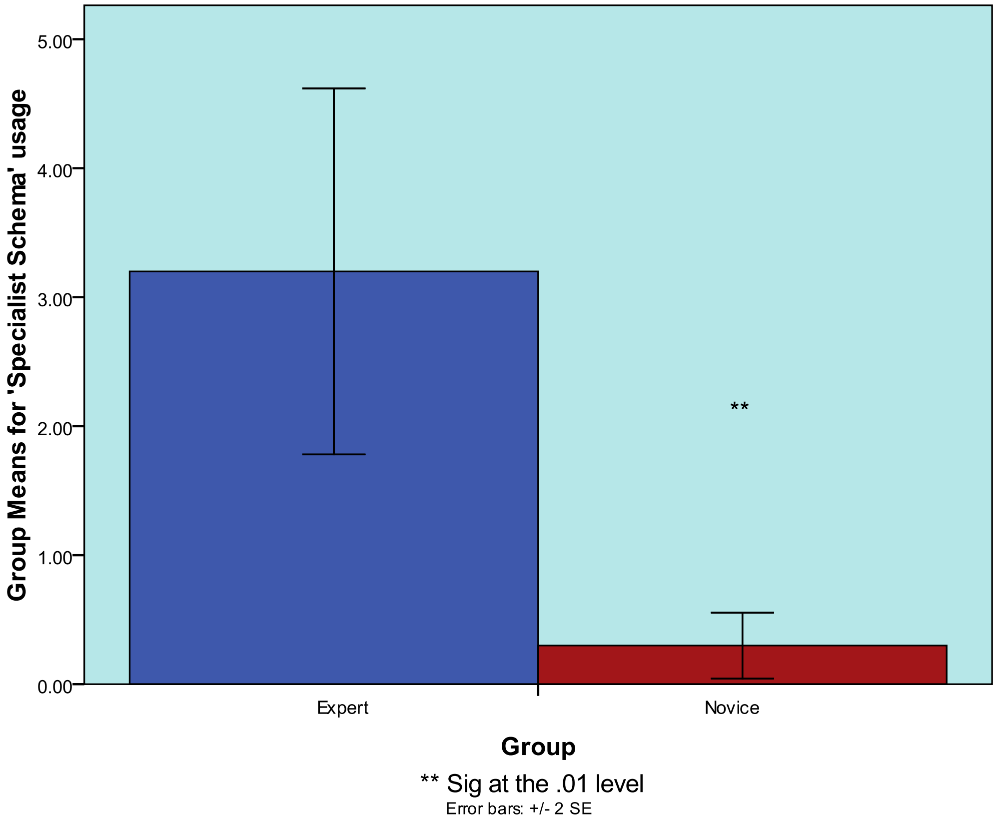


Figure 5.15 Group means for protocol code '*Specialist Schemas*'

5.4.4. Interrater reliability for the Protocol Analysis

The analysis of the participants' protocols had necessitated the allocation of one of the 14 codes to words or phrases recorded during map study. There was an element of subjectivity in this process and to assess the reliability of the results half the protocols were re-examined by an independent assessor and the results compared.

Four of the codes were of special interest as these had highlighted group differences. Of these, *Use of Specialist Schemas*, *Geographic Boundaries*, *Inferring Height* and *Independent Features* correlated at .81.84 .88 and .72 respectively. The *Independent Features* code had caused some difficulty as some features, such as woods fell into another category (*Remote Feature*) depending on distance and personal interpretation. Nevertheless for all four codes the combined reliability was .81.

5.4.5 Analysis of map materials

The 10 *probe* slides consisted of eight locations with geographic or man-made features as boundaries and two with remote features. Inspection of the participants' scores for correct *target* slide selection showed that for the location with a remote station, only six participants from each group matched the *probe* with the *target* slide. The location with a remote bridge was matched with the corresponding *target* location by 14 participants in each group.

As a result both groups had combined scores of 20 for the two remote features slides and when these scores were compared to their scores for the eight slides with geographic boundaries, no significant differences between the experimental location sets emerged either for the Experts, $F(1,8) = .139$, $p = .72$ or the Novices, $F(1,8) = .103$, $p = .756$.

So although the two remote feature slides represented a very small sample size, the participants' performances appeared to be consistent across the two types of location comparison tasks.

Inspection of the accuracy scores showed that both groups performed badly on slide 10 (Upton Cross). Only six of the Experts and one Novice identified the correct *target* location (Aklegate), choosing instead the similar sounding *distractor* (Tressinick Cross). Given that the *distractor* was highly similar in spatial congruence and also shared a similar sounding descriptive name it was quite possible that for this slide the Experts were persuaded by the strong semantic similarities rather than the similarity of geographic features shared by *probe* and *target*.

5.4.6 Evidence to support the first research question

Research Question 1: *Do expert map readers employ cognitive schemas such as templates when engaged in a map comprehension task?*

Evidence of the use of schemas by the Expert group was obtained from their verbal protocols. The Expert group made more use of '*Geographical Boundaries*' and the integration of those features into known configurations in order to visualise the extent of the boundaries for each location. The Expert group also described locations within prototypical configurations in their '*Specialist Schemas*' significantly more often than the Novices. The use of these codes may have increased efficiency in the processing of map features during surface search by incorporating top-down specialist knowledge during encoding. This was a reliable indication that the Experts were employing cognitive schemas during the map study and location comparison tasks.

Inspection of the eye-tracking data provided detailed records of the study patterns employed by participants. Since the use of cognitive schemas is generally associated with improvements in information processing, the Expert group might have been expected to complete the comparison task more quickly than the Novices. This was not confirmed. The Experts were not significantly faster during comparison of *probe* and *distractor/target* locations. Although it could be shown that the Experts placed different emphases on which features they processed, they nevertheless employed inspection patterns of the three locations which were almost identical to the Novices.

5.4.7 Evidence to support the second research question

Research Question 2: *Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping features according to familiar patterns?*

The construction of the composite slides incorporated a *target* location which was similar to the *probe* by virtue of the abstract roles played by the features adjacent to the location. It also contained a *distractor* location which was highly similar in spatial layout to the *probe*. If the participant failed to recognise the similarities of the abstract roles in the *target* location, the default selection was therefore the *distractor*. Given that fewer than half of the Novice participants' selections were for the *target* slide it can be assumed that the Novices, at least, were using the visual congruence of the *probe* and *distractor* slides to judge similarities in location boundaries.

The Experts, although making significantly fewer choices based on visual similarities, nevertheless did use these criteria for over 40% of their choices. Confirmation of this was provided in the protocols of Experts in which the group occasionally described the configuration of roads as very similar and this determined their selection of the *distractor* location.

One Expert accurately identified the experimentally generated dilemma with the commentary: '*The brain says right hand side (target) but aesthetically to look at, left (distractor) looks better' (rec18 1.18).* This Expert then chose the *distractor* location as the most similar to the *probe*.

Evidence from both the eye-tracker data and the verbal protocols therefore confirmed that Experts did on some occasions use pattern recognition techniques in their judgement of location similarity.

5.4.8 Evidence to support the third research question

Research Question 3: Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping features according to abstract roles?

By selecting the *target* slides the Expert group had demonstrated that they judged location similarities to be based on the abstract roles of features for more than half of the locations they inspected. This provided evidence to suggest that features contained within the prototypical configurations populating the Experts' cognitive schemas may well be processed according to their abstract roles as well as their spatial similarities.

The eye-gaze data confirmed that Experts had devoted more of their visual attention to geographic features, particularly hills and rivers. Many of these features had been selected in the map extracts for the functional roles they played in the determination of location boundaries. Similarly the participants' verbal protocols provided further confirmation that the Experts were identifying the functionality of geographic features and employing specialist schemas which incorporated the physical roles performed by features significantly more often than the Novice group. Taken together, these results provided compelling evidence that the Experts had processed features according to the abstract roles they fulfilled in determining location boundaries.

5.5 Discussion

This section provides some brief observations on the characteristics of the two groups of participants before discussing the results as they relate to each of the three research questions in turn.

5.5.1 Characteristics of the participants

The recruitment of 20 Ordnance Survey field surveyors for the experiment provided a concentration of the very highest levels of map-reading expertise within an Expert group. The performance of this group in a demanding task of map comprehension was to be assessed by comparison with a far less experienced group of map readers. However it was important that the Novice group were fully competent contour map readers in order that they were capable of recognising and assessing the features which might constitute natural boundaries within a topographic landscape for the location comparison task.

5.5.1.1 Participants Experience with Maps

The rationale for the administration of the ‘Experience with maps’ questionnaire to each participant was therefore twofold. In the first instance it was essential to establish that the groups did differ in their levels of map reading experience. Not surprisingly, the questionnaire provided this confirmation.

Secondly, the questionnaire provided evidence that each of the Novice group had experience at reading contour maps and had sufficient competence to engage in the planned experimental task.

5.5.1.2 Participants and Gender Effects

The Expert group consisted of 17 male and three female surveyors while the Novice group was predominately female with only five males in the group of 20. It was necessary, therefore, to consider that some of the experimental effects might have been due to gender imbalances between the groups.

While this was possible it was considered unlikely for the following reasons. Firstly the literature on gender effects in map reading is inconclusive across the full spectrum of map-reading tasks. There is no evidence, for instance, to suggest that female participants process map data differently from males during map study. This experiment required participants to analyse features adjacent to locations and conduct a comparison task with no requirement for spatial orientation in the real world, a task for which the female map users have occasionally performed less efficiently than males engaged in the same task.

Secondly, the level of map reading competence in both groups was likely to be well above the datum at which gender effects might seriously impair performance at the experimental task prescribed.

5.5.1.3 Age of Participants

The mean ages for each group were significantly different. The Experts were in their mid 40s while the Novices had a mean age of 27. While it would have been ideal had the two groups been matched for age it was neither practical to recruit younger field surveyors, since there are very few of them, nor possible for practical considerations to recruit 40 year-old competent map readers within the general population.

It was necessary therefore to consider the possibility that the results relating particularly to task completion times may have been affected by the differences in participant ages. The literature reporting the effects of aging and performance in cognitive tasks suggests that task completion times would almost certainly have been affected by the disparity between participant ages.

For this study therefore two considerations applied. Firstly the task completion times were to be treated with caution for the purposes of making group comparisons. Secondly, and perhaps more relevantly, it was possible that the Expert group, being tested within their areas of expertise, might have applied a more conscientious approach to the task than the student participants. If this had happened it may have resulted in extended study times for the Expert group as once the Experts had conducted the task they then reviewed their evaluation in the interests of greater accuracy.

5.5.2 Discussion of the first research question

Research Question 1: *Do expert map readers employ cognitive schemas such as templates when engaged in a map comprehension task?*

Examination of the eye-tracking data and the participants' verbal protocols revealed some clear differences in the map study procedures adopted by each group. Firstly, the Expert group consistently studied the area within the urban confines of the location to a greater extent than the Novices. Secondly, the Experts grouped features as they described the locations in their protocols. Thirdly, features which constituted geographic boundaries were attended to by the Experts as represented by their eye-gaze data and described in their protocols more frequently than in those of the Novice group. Finally, the number of instances in which the Experts were observed employing specialist knowledge was reliably higher than the Novices.

From these findings a pattern of the cognitive processes employed by the experts emerged. The Expert group appeared to spend more of their study time on the immediate borders or within the urban confines of the studied location. However, they nevertheless observed more of the geographic features beyond the adjacent urban edges that had been selected as likely to constitute the location outer boundaries. This perception and identification of the geographic features had therefore been achieved by the Experts with less processing time and fewer visual inspections than the novices. This suggested a familiarity with the overall configurations studied. This greater comprehension may have been provided by the employment of specialist knowledge during the surface search of features within each map location. The verbal protocols provided further confirmation for this interpretation. In their descriptions the Experts appeared to use specialist schemas to integrate features within prototypical configurations during the early encoding of features.

An example was provided in recording 27 '(*Tressinick Cross*) *..on a cross-roads..very hilly round here looks like its on top of a hill because there is no river near by…so it's on top of a hill with a river to the North but it's a linear feature*. (*rec* 27 11.15). In this example the Expert had correctly identified that the *distractor* location was similar to the *probe* by being on a cross-roads but, unlike the *probe*, was situated on a hill. The Expert had identified the elevation firstly from interpreting the contour lines and secondly by searching for any evidence of rivers close to the location.

The use of schemas would have provided Experts with a more efficient method of processing the map features initially during the encoding and subsequently for the comparison task. It might have been anticipated, therefore, that the study times for the composite slides in which the *probe* was being compared to the *distractor* and *target* locations would have been shorter for the Expert group. This result was not observed.

Closer examination of the eye-gaze data showed that the two groups employed very similar study patterns during inspection of the composite slides. Both groups allocated approximately 25% of their overall study time returning to the *probe* picture and the remaining 75% studying the newly present *target* and *distractor* locations. For this task Experts actually spent longer at almost 40 seconds (M = 39.8, SD = 20.8) compared to the Novices 30 (M = 30.3, SD = 15.3). However, the groups did not differ significantly because the individual differences within the groups, as demonstrated by the high SD values were also large.

The question remained, therefore, as to why the use of schemas did not facilitate the Experts' information processing sufficiently to produce shorter study times for the comparison task. Four possible reasons were considered. Firstly, it was possible that the Experts were not using cognitive schemas or that they had not contributed to increased efficiencies during information processing. The evidence in this study suggesting that Experts were integrating map features during encoding had been obtained by a number of experimental measurements and was therefore considered reliable. The Experts had appeared to be employing cognitive schemas. Similarly, within the literature on cognitive schemas, there had been considerable agreement relating to the enhanced speed of processing when information is chunked and processed within schemas. It would be surprising, therefore, if the use of schemas in a map comprehension task did not confer the same advantages of faster processing of schema-related data as those extensively reported in other disciplines.

It was considered, therefore, that the Experts had been using schemas but for this experimental task they had not contributed to faster information processing.

Secondly, it was possible that the large standard deviations within both groups had masked an experimental effect which might have confirmed a genuine difference between the groups. Further inspection of the study times revealed that the mean times for the Experts had been skewed by approximately a quarter of their number taking considerably longer than the remaining group members. However a similar effect was also evident within the Novice group and removal of the outliers still failed to provide significant group differences. The Experts simply had taken at least as long as the Novices in the comparison task.

A third possibility was that the differences between the group ages had contributed to the counter intuitive result. With a mean age of 46 the Experts were nearly 20 years senior to the Novices. The increased decision times due to the slowing of cognitive functioning with age among the experts might have countered the improvements expected from the use of schemas. However, the level of expertise amongst the Expert group was high. Any age-related reductions in cognitive performance would have had to be excessively large to overcome the enhancement in performance due to schema use and task familiarity. The difference in ages between the groups was not therefore considered the likely reason for extended task times in the Experts.

A final consideration was that the groups had different levels of commitment to the experimental task. It had been clear from the audio and video records that a large number of the Expert group had carefully deliberated before making their selections. So too had some of the Novices but overwhelmingly the Experts had approached the task with a far higher motivational level than the students. While the students were merely participating in an experiment paying a £10 fee, the field surveyors most likely had viewed the task as a test of their professional competence. In this case, even if they reached their decision in the map comparison task before the novices, it was possible that they reconsidered their selections at least once more before recording their choice. The Experts were not instructed to reach their judgements within a minimum time and their performances correspondingly reflected very measured and well considered judgements. This explanation thus seemed the most plausible as the reason why Expert comparison task times had not differed significantly from those of the Novice group.

Conclusion Results from both the eye-gaze data and participants' verbal protocols provided evidence to support the contention that the Expert group was integrating features within prototypical configurations and employing cognitive schemas during map study. The use of these schemas did not, however, contribute to faster performances by the Experts in the comparison task probably due to their extended and conscientious deliberations prior to selecting a match for the *probe* location.

5.5.3 Discussion of the second research question

Research Question 2: *Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping features according to familiar patterns?*

Pattern recognition formed the basis of information processing for Gobet's chess participants when they integrated board information into templates. The participants in this experiment were engaged in a demanding comparison task requiring detailed study of visual presentations of map data. There was good evidence to show that during this exercise the Experts had been employing cognitive schemas equivalent to templates for studying and encoding the presented map information. It was expected therefore that for at least some of the participants the comparison task would be driven by recognising visual similarities in the spatial configurations of the presented map extracts.

To test for this assumption, the *distractor* location had been selected in every case to provide a location of similar size to the *probe* and surrounded by features with high geometric congruence to those in the *probe* slide, albeit generally at a different orientation. As anticipated, the results showed that the *distractor* was chosen as the location with boundaries most similar to those in the *probe* slide by the Novice group for more than half of their choices. Pattern recognition had therefore been the overriding consideration for the Novices in the comparison task.

The Experts had significantly fewer instances of choosing the *distractor* slide but were nevertheless shown to have chosen it for 45% of their location comparisons. In some of the location comparison tasks therefore, the Experts had also employed pattern recognition techniques during the comparison of locations.

When the judgement of what constituted the boundaries of a location became a particularly difficult task for both groups it appeared that the fall-back position was to select the location which was most visually similar. This situation occurred for the first location with a remote feature (Cowden) in Slide 9. The remote feature was a railway station bearing the village name which could be considered as representing the extent of the village boundary. The *distractor* slide lacked a remote station but had a geometrically identical pattern of roads. Fourteen participants (70 %) from each group selected the *distractor* slide. This indicated that when there had been considerable doubt about which features contributed to the boundary classification task, participants from both groups resorted to pattern matching.

Of course, one criticism might be made that the experimental design only provided two options for comparison with the *probe* slide. The *target* slide was similar by the functionality of the physical features adjacent to the location while the *distractor* provided a solution as a visual match. Participants failing to appreciate the roles played by the physical boundaries in the *target* slide therefore had only the *distractor* slide to choose.

From this viewpoint it could be argued that the participants may not have been choosing to pattern match, they may simply have had no alternative choice from the *target* apart from the *distractor*. This problem could have been eliminated by including a neutral location in which there were no visual similarities and no similarities by virtue of the abstract roles to the *probe* slide. Participant choice for either *target* or *distractor* would then have been more likely to have been made on a free choice based on the criteria of similarities in either the visual patterns or the functionality aspects of the boundaries. This option had been considered at the early experimental design stage but was disregarded as introducing an additional level of complexity to the composite slides which was not entirely justified.

The key aim of the study had been to identify if expertise in a map comprehension task included the recognition of abstract roles of features. This was largely achieved as discussed in the following section. Identifying the contribution of pattern recognition in a task of judging boundary similarities, therefore, constituted only a secondary ambition of this study. Within the limitations discussed this was satisfactorily demonstrated. Features were grouped according to the visual patterns they presented on the map for some of the comparison tasks by participants from both groups.

Conclusion Both Expert and Novice participants grouped features according to recognisable visual patterns when engaged in some of the location comparison tasks. The Expert group however employed pattern recognition in their cognitive schemas on significantly fewer occasions than the Novice group.

5.5.4 Discussion of the third research question

Research Question 3: *Does the implicit specialist knowledge held in their cognitive schemas assist expert map readers in identifying and grouping features according to abstract roles?*

The primary purpose of this study had been to seek an answer to this research question. All locations originally designated as *probe* locations had been carefully selected to contain geographic features which fulfilled an abstract role in determining the extent of the location boundary. Features performing the same or similar roles were contained in the *target* slides. Participants were thus required to identify firstly the function of the features in determining the boundaries in the *probe* slide and then secondly to search for features performing the same or similar roles in the *target* (or *distractor*) slides. Quite intentionally, the experimental task had been designed to be demanding in order to test the specialist knowledge of the experts.

Despite the difficulty of the task the results nevertheless indicated that the Experts had used the abstract roles of features as their criteria for selecting the *target* locations for 55% of their choices. This was significantly higher than the number of correct selections made by the non-experts.

But had the Experts really been identifying the roles of the features to reach their judgements of location similarities? The geographic features adjacent to the *probe* and *target* locations had been selected specifically for the functions they fulfilled as the probable location boundaries. Both the eye-gaze data and the verbal protocols confirmed that these geographic features were attended to significantly more often by the Expert group. This suggested that the Experts had identified the functional roles of features and attended to them.

In contrast, a different pattern emerged for independent features, such as woods and roads remote from the subject location and not contributing any function as a boundary. Many of these features were attended to in the eye-gaze data and verbal protocols of the Novice group more frequently than in those of the Expert group.

However, it should be remembered that this result had been obtained by group comparisons and therefore may have occurred for one of two reasons. Either the Novice group had directed more of their attention to irrelevant features, or the Expert group had disregarded sooner those features which they recognised as not serving any function as boundaries. In either case, the clear picture from these results was that a more focused approach had been adopted by the Experts as they studied and comprehended the boundary features which had been included for their functional rather than their spatial similarities.

Examples of the identification of function within the features studied were provided in the following Expert protocols: '*Bounded by the river' (rec 24, 05.11), 'Callington is hemmed in by upland areas' (rec 26 02 .14), 'Main boundary there is the river to the West' (rec*

27 02.47), 'Upland areas on both sides squeezing the settlement in between' (rec 26 05.26),' 'Wadebridge is both sides of the river whereas Blandford is not' (rec 11 06.28).

So, if the Experts were identifying the functional properties of features as suggested by the evidence examined, were they also grouping these features within their schemas according to their abstract roles?

Two of the experimental findings lent support to the proposition that they were. In the first instance, the eye-gaze data had shown that there were significant between-group differences in the study patterns. Experts were consistently directing more of their visual attention than the Novices within the strict confines of the urban area. This might have indicated that the Experts had not attended to the features which were outside the location boundaries.

Yet the verbal protocols revealed that the Experts had both observed and encoded the geographic features more frequently than the Novices. In order to have done this with fewer fixations, the Experts must therefore have processed these features more efficiently. This may have been achieved by the use of schemas in which the features constituting the boundaries had been grouped into a prototypical configuration enabling better processing and comprehension of the visual data studied. Since the geographic features were more relevant by function than were features providing visual similarities, then Experts had indeed grouped features into their schemas according to the functions they were performing.

The second experimental finding which supported the suggestion that the Experts were processing features according to their abstract roles was obtained from the Experts' specialist schemas. Instances where the Experts were observed employing specialist knowledge in their verbal protocols had been recorded. Examination of these descriptions provided further evidence of how the features had been categorised according to their function during the processing of map information. Some of these examples were highly illuminating: '(*Dundon).....it's on a very flat area with a risk of flooding which is why they have positioned the village between the hills' (rec 27 03.16)*. This example clearly illustrated how the features had been integrated within a schema incorporating relative elevations. The flood plain had been identified as unsuitable as a site for the village by virtue of its low elevation. The edge of the flood plain, therefore, constituted one boundary. The hills provided adjacent boundaries by virtue of their raised elevations and had restricted the development of the village along the slightly elevated valley floor between the hills. The expert had thus encoded all the adjacent features by the roles they were fulfilling as boundaries for the village settlement.

In another location slide the same Expert noted '*there is a National Trust area to the East so there might be a big house which is causing the boundary on the Eastern side' (rec 27 04.39).* In this description a feature not actually included on the map had been assumed to exist in conjunction with the *NT* symbol. The area had then been identified as a potential boundary by its function as a likely area for preservation into which the town could not be developed. This provided an interesting example of the use of schemas to construct a representative scenario from an incomplete set of map features.

A further example of the identification of the functional properties of administrative as well as physical features was provided in a protocol for the study of a town location *'Definitely see the county boundary as the edge of Wetherby' (rec 18 10.27).* The boundary between North and West Yorkshire looped around the town of Wetherby and although difficult to identify had defined exactly the irregular shaped outer edge of the town development. In this example there had been no obvious physical restriction to the expansion of the town but the knowledge that county boundaries might function in the same way as a physical geographical barrier had determined how the Expert had encoded this feature.

Finally, one Expert observed *'Some kind of new ring road that's gone round it (Dorchester)' (rec 25 06.57)* which contrasted well with another expert statement '*the A24, the old London road used to go up that way' (Ashington) (rec 26 06.43).* These two examples provided evidence that where the Experts studied man-made features they applied specialist knowledge to ascertain the temporal sequence which had governed the evolvement of the town and its associated features. The locations had thus been studied within an understanding of how the features may have acquired properties because of the town extent or conversely had properties which may in turn have restricted the eventual urban development. Again the functional properties of the man-made features appeared to have been considered within the Experts' evolving schemas.

Conclusion Results from the eye-gaze data and the participants' verbal protocols provided converging and persuasive evidence that the Expert group had identified the abstract roles of the geographical features in forming the location boundaries. During the location comparison tasks there was again reliable confirmation that the Experts were employing specialist schemas in which features had been grouped according to the functions they performed as the location boundaries.

5.6 Summary of Findings

The experimental hypothesis had been that the Experts would recognise the abstract roles of features presented on a map and would integrate these features within their cognitive schemas according to the abstract or functional roles they fulfilled.

The experiment successfully demonstrated that the hypothesis was correct. Although expert map readers do employ pattern recognition techniques to process some map data, the results from this study showed that the functional roles of features were also crucial in determining how these features were grouped within the Experts' schemas.

The first research question required confirmation that the Expert participants had employed cognitive schemas during the processing of map-related information. Inspection of the verbal protocols and eye-gaze data provided this verification. In their verbal protocols the Expert group referred to geographical boundaries and employed specialist schemas in which the physical features constituting the location boundaries were integrated.

The eye-gaze data revealed that the Experts focused more of their attention than the Novices within the urban confines of the location and on the physical features forming the boundaries. In their protocols, however, the Expert group provided accurate descriptions of the location and its surrounds which suggested that they had processed peripheral physical features with fewer fixations. The integration of features into prototypical configurations and the employment of specialist knowledge during information processing were commensurate with the use of cognitive schemas by the Expert group.

Although the Experts had employed cognitive schemas, the study patterns for the composite slides were similar across the groups and Experts were not significantly quicker in the location comparison task. This latter finding may have been due to the adoption of a more conscientious approach to the experimental task by the Expert group.

The second research question had asked if Experts employed pattern recognition to integrate features within their cognitive schemas. The *distractor* slide was the location which was visually similar to the probe location and this was chosen by the novices for 55% of their comparisons. The Experts, who had been shown to be processing features within their schemas, selected the distracter slide for 45% of their choices, thereby indicating that they had used pattern matching as the criteria for at least some of their decision making. There was evidence in the verbal protocols that participants from both groups referred to visual similarities of features during the encoding of map data, but the groups had not differed significantly in the number of instances of ‘pattern matching’ or comparing ‘location shape’ within the protocol analysis. While it was evident that the Experts had employed pattern recognition during the processing of map data it was also noted that the *distractor* slide had been the default selection and may not have been chosen specifically for its visual congruence with the probe on every occasion.

The possibility that Experts had encoded features according to their abstract roles formed the basis of the third research question. The Expert group selected the *target* slides for 55% of their comparison tasks confirming that they identified the similarity between the *probe* and *target* locations by the abstract roles of the features constituting the boundaries. Detailed confirmation of this result was provided by examination of the eye-gaze data. Experts studied the geographical features which had been selected for the functions they performed as location boundaries more frequently than Novices. Experts were also more focused in their visual search, recording fewer fixations outside the urban extent and immediate boundaries of each probe location. By identifying the saliency of the geographic features in the overall landscape with fewer fixations, the Experts confirmed they were encoding the boundary features within a specialist schema which categorised features according to the importance of their functional roles.

In their verbal protocols, the Experts also made more references than Novices to geographical features and their functions whilst they employed specialist schemas on significantly more occasions. Experts were also recorded integrating boundary features within their schemas according to their functional properties.

Taken together, the results provided reliable evidence that for a task involving boundary comparisons, Expert map readers employed cognitive schemas in which features were grouped according to their abstract roles.

5.7 Overall Conclusions

The conclusions based on the three research questions are provided below.

Research Question 1: *Do expert map readers employ cognitive schemas such as templates when engaged in a map comprehension task?*

- The study patterns of the Expert group were based on specialist knowledge of the role of geographic features in forming the boundaries of locations.
- The Experts grouped features as they studied the map data.
- The use of specialist schemas to provide enhanced comprehension of the terrain was consistently demonstrated by the Expert group.
- The surface search of map features appeared to be driven by the knowledge held in the Experts' cognitive schemas and the nature of information processing closely matched that described by Template theory.

Research Question 2: *Does the implicit specialist knowledge held in cognitive schemas assist the expert map readers in identifying and grouping features according to familiar patterns?*

- The *distractor* slide was the location with high visual congruence to the *probe* and was chosen by the Expert group for 45% of their comparison tasks.
- The Novice group chose the *distractor* for 55% of their comparisons.
- Descriptions of locations in participants' verbal protocols included feature comparisons by reference to similarities in spatial configurations
- Participants from both groups employed pattern recognition techniques for some of their location comparisons. However Experts made significantly fewer selections based on visual similarities.

Research Question 3: *Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping features according to abstract roles?*

- Experts judged location boundary similarities by the functional aspects of geographical features for more than half their comparison tasks.

- Experts studied and described the roles of geographical features more frequently than the Novices as demonstrated by their eye-gaze data and verbal protocols.

- The Experts identified the roles of the physical features in relation to the surrounding landscape with fewer fixations than the novices, suggesting these features constituted elements of their prototypical configurations.

- For more than half of the comparison tasks, the Expert group employed specialist schemas in which features were encoded and retrieved according to their functional and abstract roles.

Chapter 6 Expert Performance in a Map Comprehension Task for Remote & Grouping Features – Experiment 3b

6.1 Introduction

This study was an extension to the experiment described in the previous Chapter (5). Again the aim had been to examine expertise in a map comprehension task but this time with a study that introduced locations with conceptual boundaries in addition to those formed by physical features.

In Experiment 3a, it had been hypothesised that the Expert map readers would identify the abstract roles of geographical features in forming boundaries adjacent to locations and process the features in their schemas according to the abstract roles. This was successfully demonstrated. The Expert group were observed to be attending to geographic boundaries, comprehending the functions they were performing and integrating these features into their schemas for the location comparison tasks.

The experimental task had demonstrated that the expertise of the experienced map readers lay in their deeper understanding of how the extent of place locations might be defined by adjacent geographical or man-made features performing the functions of boundaries. However, the outer extents of a location are not always dependent on physical boundaries alone. Remote features which are integral to, or closely associated with, a location might extend the immediate urban area to include the feature within an enlarged boundary. Similarly, grouping concepts might result in one or more adjacent locations developing into a larger grouped location which then assumes an identity based on the shared grouping feature. In such cases the remote feature or the factor which integrates more than one location into a group might be processed for their functional roles in the same way experts appear to process geographic boundaries.

Several studies have addressed the complex problem of defining place extents and these are addressed in the literature review as they also provide the rationale for including non-geographical features within this experiment.

The limited number of location comparisons employed for Experiment 3a had been governed by the requirement to obtain verbal protocols from all participants and this had been expected to extend the study times. As a result, the opportunity to include conceptual features in the experimental task had been limited. This additional experiment was designed therefore to engage the experienced field surveyors in a task which provided a broader perspective of map reading expertise by the use of a more comprehensive set of map locations and without the requirement to provide a verbal commentary.

The overall aim, therefore, was to evaluate whether very experienced map readers also process remote or grouping features within similar cognitive schemas to those in which physical boundaries are identified and processed. The experiment was run with each participant on completion of the task in Experiment 3a.

6.2 Research Design

This section provides the three research questions to be examined. The literature relating to this study is then briefly revisited and the experimental design employed for Experiment 3a is examined for its suitability to answer the research questions.

A modified experimental design is then described together with the justification for its selection.

6.2.1 The three research questions

The first research question formed the central hypothesis for the study reported earlier in Chapter 5 but was again directly relevant for approximately half the comparison tasks in this study and indirectly relevant for the remainder. Research questions 2 and 3 have not been addressed previously in studies of map reading expertise.

1. *Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping geographic features according to abstract roles?*

2. *Do expert map readers integrate the abstract roles of remote but associated features within their schemas of what constitutes the outer extent of a locality?*

3. *Do expert map readers integrate the abstract roles of conceptual grouping features into their schemas of what constitutes the extent of the community boundaries?*

6.2.2 Literature relating to cognitive schemas, map expertise and semantics of 'place'.

The work of Gobet (1997) and Linhares and Brum (2005) were examined in the previous experiment for the contribution these authors have provided to our understanding of spatial information processing. Although their work had been in the field of chess, it was observed that both the pattern recognition described by Gobet and the grouping of features according to their abstract roles method of processing suggested by Linhares were equally relevant to the processing of map data. Indeed the previous experiment provided reliable evidence that the Expert participants had employed both types of information processing for the location comparison tasks although ultimately had favoured the use of abstract roles for more than half their choices.

It could be assumed, therefore, that the geographic features had been incorporated into the Experts' cognitive schemas to assist in their assessment of the location boundaries. However, assessing the extent of a location is almost invariably more complex than merely recognising the physical features which enclose the urban area. Often the physical boundaries of a location are ill defined or merge with adjacent developments (Bennett & Agarwal, 2007), administrative boundaries are unclear or even disputed making allocation of places within clearly defined regions difficult or even impossible (Talen & Shah, 2007) and in some areas there is a lack of consensus even amongst residents as to the extent of their neighbourhood (Davies, 2009). A concise summary of this dilemma is provided by Agarwal (2005) 'the meaning of place is not completely explained and understood since the ontological commitments in place range from abstract theoretical conceptualisations grounded in experiential dimensions, to social formations and cognitive conceptualisations'(p70).

Notwithstanding the difficulties, the increased use of GIS (Geographic Information Systems) applications requires detailed knowledge of the extent of place boundaries to enable accurate compilation of place data in computer generated displays. In addition, in-car navigation devices and internet search engines providing travel directions require consistent definitions of the extents of programmed locations. This has driven the need for a more formal approach to the definitions of geographic spaces.

6.2.2.1 Theories of Place

A representational theory for place has been addressed in two recent studies (Agarwal 2005, Bennet & Agarwal, 2007). In the first study (Agarwal 2005), the author provided residents of Nottingham (n=50) with questionnaires testing their concepts of place, neighbourhood and region. The consensus that emerged produced a spatial hierarchy in which a *neighbourhood* was contained within a *place* which in turn was contained within a *region.*

These findings were integrated into the second study (Bennet & Agarwal, 2007) in which the semantic categories of place-related expressions were further considered. At the outset the authors examined the functions of places and concluded that these might be considered in three categories. Firstly, places locate objects within a group. Secondly, places host associated objects within a sub-space which may be further embedded in a larger space. Finally, places anchor the objects which form the place to permanent physical areas of the earth's surface in a global reference frame. Yet while these underlying principles might determine the physical extent of a place, two further factors govern how places are identified in map or GIS displays. These factors are continuity and similarity. Visual perception relies on identifying boundaries and for recognition as a single entity an object, or place, must be perceived as having properties of continuity. At the same time a place requires a degree of homogeneity perhaps by colour or pattern in order to distinguish it from its adjoining areas.

Within the classifications of continuity and homogeneity, the authors briefly examined the more complex geographic and sociological concepts which might determine place boundaries. A précis of these considerations is provided: control, exercised by administrative authorities or shared jurisdiction; proximity, defining connectedness by metric distance; aggregation of features with similar and related properties and; systemic grouping incorporating heterogeneous parts within an integrated whole.

Yet, while Agarwal and her fellow researcher had identified some of the physical properties which might have defined place extents, it was clear from the following sections in their paper that the difficulties in attempting absolute definitions for areas such as region, territory, district and sector introduced ambiguities and uncertainties which could not be fully resolved. Indeed, the role of features in defining or extending the spatial limits of urban developments was not addressed in any detail. The authors thus concluded with a refreshingly honest admission. Their intention had been to provide a ‘general logical theory of place’ (p18) but the variety of linguistic expressions and the range of interpretations within the descriptions they encountered during their research had taken the task requirements beyond the scope of their study. However, if their research had failed to provide a definitive ontology of geographic spaces, it had at least identified the highly complex nature of the task and provided a framework to study the semantics of spatial descriptions and their relationships.

More recently, researchers at Ordnance Survey have conducted two detailed studies into the concept of what might, spatially and semantically, constitute a ‘place’. In the first study the researchers (Davies, Holt, Green, Harding, & Diamond, 2008) interviewed GIS users (n=56) at their workplaces to identify participants’ personal definitions of the word place as they used it in their work. For half the participants place, place-name or neighbourhood were identified as a key concept in the use of their GIS data. For the majority of participants ‘place’ referred primarily to localities or neighbourhoods followed by sub-urban locations. At a lower frequency of occurrence the descriptions given were of urban areas, housing estates, towns and villages.

When the analysis of user requirements was evaluated it was seen that almost all the participants who identified knowledge of ‘place’ as a requirement for their work task also required the names of at least some of the places. Interestingly, well over half of this group also required the extents of the places depicted despite an appreciation that allocation of place extents often resulted from vague and inaccurate spatial interpretations. Although this study did not attempt to identify the features which may contribute to place extents the authors nevertheless provided a comprehensive discussion of how approximations in place extents encompassed in the broader concept of vernacular geography might be accommodated in future GIS modelling.

In the most recent study Davies (2009) examined the concept of place as defined by a set of physical and sociological criteria reportedly employed by local inhabitants when defining their local areas. The physical criteria included features such as adjacent major roads and railways acting as boundaries, metric distance of amenities such as church or shops but also included, administrative or electoral boundaries and postal codes. The sociological categories referred to perceptions of social cohesion such as: ‘people like us’; architectural similarities in terms of housing developments; concordance between map name and locally used name and; similarities with or differences from the surroundings by age or other sense of belonging. In an interesting experimental hypothesis the author had predicted that if places could be classed as concepts then they might be subject to the variability and distortions that occur in attempts to classify concepts in different fields. This prediction had been based largely on the work of Barsalou (1985) and Hampton (2007) and a brief review of this work is now included.

6.2.2.2 Places as Concepts

Barsalou (1985) theorised that individuals categorise objects using three principles. Firstly, they judge an object on how closely it matches an ideal associated with the perceived goals of the category. Secondly, they assess how typical it is to the central tendency of the category. Thirdly, people recall the frequency of instantiation or number of occurrences the object has been identified as a member of the category. By the use of these principles a graded structure representing typicality is constructed in working memory drawing on information held in Long Term Memory. However, Barsalou suggested that for some decision making the criterion used might be central tendency but for others the task characteristics might bias the decision towards a perceived ideal. Thus, depending on the context of the scenario both the nature and the emphasis of the information used to construct the concept might vary considerably.

In this sense, concepts (of entities) were not invariant and unchanging but were dynamically constructed representations having particular relevance to the requirements of each situation.

The implications for individual assessment of the concept of place within such a framework would be significant. It could be anticipated that individual judgements of a place might be dependent not necessarily on consistent comparisons with other similar locations but might show considerable variance according to the functional requirements of the perceived task.

Hampton (2007) has proposed an alternative account to describe how vagueness of a concept such as the definition of place can be explained by the psychological intuitions which arise when the concept is evaluated according to its typicality for category membership. These cognitive processes, the author suggested, determined the characteristics of each individual's conceptual representation system. In line with Barsalou's description of how individuals compare an object with known examples close to the central tendency of the category, Hampton also proposed that concepts are structured on comparisons with a representation of an envisaged prototype. The author described a mathematical model in which the degree of membership a concept may have within a category was directly related to its similarity to the known prototype of the concept. Successful categorisation of an object, however, could be directly affected by three factors: the representation of the object itself; the representation of the category or; the threshold of similarity required to classify the object within the category. All three of these were subject to variation between and within individuals and therefore contributed to vagueness in categorisation of concepts.

6.2.2.3 Neighbourhoods as Concepts

Hampton's description of how vagueness exists in concepts appears to be relevant to the vagueness which surrounds attempts to define the spatial extents of places. In defining a neighbourhood it is not always clear that the representation of the locality considered has any or all of the properties for classification as a neighbourhood. The representation of what categorises a neighbourhood is similarly not crisply defined. The degree of similarity of an area to an assumed prototypical neighbourhood provides the threshold for allocation into the category but will vary across individuals and the assessment tasks.

Having established the difficulties in defining place as provided in the selected literature, Davies examined the consistency of decision making in a group of experienced map readers across three distinctly different scenarios. Field surveyors (n= 22) from Ordnance Survey completed questionnaires in which they were presented with three exercises of identifying locations. For the first scenario, the participants were required to recall a town they had recently surveyed and to make judgements on whether a location in that town could be regarded as being in a particular neighbourhood based on thirteen grouping factors. This task was repeated for a personally selected location within the participants' home neighbourhood. Finally, the participants imagined they were moving to a new but largely unknown area and were again required to make judgements about an imagined location within the new neighbourhood.

Decision making across the scenarios was not consistent. The participants had been required to identify which features they would consider as directly influencing their perception of the place as belonging to a neighbourhood. In the work scenario the number of factors the surveyors would consider as signifying inclusiveness in a neighbourhood was similar to the sum of factors which suggested exclusivity. While this result did not differ significantly for the new area, this was not so for the home scenario. In this exercise a higher number of factors were selected defining inclusion than were identified as signifying exclusion from the neighbourhood. A significant interaction between the scenario and the decision making confirmed that the participants' concept of what constitutes place and neighbourhood had altered across their self-constructed scenarios.

The five factors which were most often considered for determining inclusion/exclusion were (in order): physical barriers; Royal Mail address; local name; administrative area and; distance from amenities. Having the same name was important in defining that a location was part of a larger community but had more bearing on exclusion rather than inclusion. The remaining features were selected by participants for their part in determining inclusion as opposed to exclusion of the location into the neighbourhood.

The author grouped the features into four categories: definitive; frequency of instantiation; spatial central tendency and; ideals. These classifications incorporated the theoretical considerations applied to concept categories identified earlier in the Barsalou (1985) literature. The criteria selected by the group most consistently in their neighbourhood judgement task were definitive features followed in order by spatial central tendency, frequency of instantiation and ideals.

From the results, Davies concluded that her participants had behaved as Hampton had predicted allowing the threshold of location membership into neighbourhood categories to alter with changes in the perceived scenario. Interestingly, the results had indicated that ideals were the least considered conceptual feature for the location and neighbourhood membership task. This was surprising as Barsalou had identified classification of an object by how closely it matches an ideal associated with the perceived goals of the category as a key feature of his graded structure. The task here had required participants to envisage different scenarios in which the perception of the functional nature of the place and neighbourhood interaction might have been expected to alter. As such, the comparison with a perceived ideal might have been expected to have received greater priority. This observation may, however, have been addressed by the authors statement that the participants were experienced surveyors trained to identify the role of geographic features in determining boundaries. Accordingly they may therefore have placed greater emphasis on physical barriers than other participants might have done.

6.2.2.4 Relevance to the Present Study

The Davies (2009) study has been examined at some length for three reasons. Firstly, it addresses a very important area of study for the GIS community. The modelling of place is problematic for all the reasons discussed earlier yet it has to be addressed if future electronic databases are to provide meaningful information. Secondly, the study has broken new ground by examining the entity of place as a concept. In so doing it has identified that the imprecision inherent in defining the spatial extent of places might also include an additional dimension of intra-personal variance due to perception of task requirements. Finally, the study has considerable relevance to the research conducted within the experiment reported here.

The notion that a place might be considered as a concept had been implicit within Experiment 3a in this thesis. In this study the emphasis of the research had been to establish firstly whether skill and expertise in map reading was dependent on the employment of cognitive schemas and, secondly, whether geographic features relating to place boundaries were grouped into the schemas according to visual or functional congruence.

Experiment 3b in this study extends the scope of the earlier experiment to examine the conceptual importance of remote features and grouping concepts in defining the spatial extent of a location. Inclusion of a remote feature into the concept of a location requires an understanding of the social fabric of an area similar to the metric distance of amenities and functional similarity of surrounding neighbourhood researched in the Davies (2009) study above. It may also require a re-appraisal of the threshold for which the spatial extents of a location may be stretched to provide ownership of the remote feature within the location entity as suggested by Hampton (2007).

Likewise individual assessment might be driven by the identification of the remote feature as performing a function considered integral to the perceived function of the community. In such an instance the feature might contribute to the overall construct of Barsalou’s prototypical ideal for a goal-derived category and would be judged as an essential feature of the overall location.

In the case of grouping features, the same considerations might apply. Villages with sub-communities possibly having a derived name, for instance Norton and Norton-sub-Hamden, might form a conceptual community in which the boundary is perceived to include both villages. Villages sharing a name and occupying separate but adjacent locations, such as East and West Ashling, might again be grouped together as one location within the principles of some perceived functional goal shared by the grouped community. As Davies found in her experiment, the threshold for including and excluding features within a neighbourhood had highlighted that sharing a common name was a more powerful predictor for exclusion decisions than for inclusion. Villages displaced spatially but sharing a common name might therefore present a problem for assessment as separate communities and be prime candidates for grouping.

In sum, as Bennet & Agarwal (2007) have observed ‘Places are the conceptual entities that enable cognitive structuring of the spatial aspects of reality’ (p2). However, as we have seen, the nature of the conceptual entity can be affected by a number of complex considerations. With an appreciation for at least some of these considerations this study aims to extend our understanding of how the extents of places are conceived with firstly, locations having remote but relevant features and secondly, when places are encompassed within sociological or historical grouping concepts.

6.2.3 Characteristics of the research design

This section briefly describes the factors which influenced the selection of an appropriate experimental design to address the three research questions.

The first research question was *‘Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping geographic features according to abstract roles?*’ This question had also been addressed by Experiment 3a reported in Chapter 5. The earlier study had found that geographical features were grouped by the Experts according to the abstract roles they performed in providing boundaries around a location. However, for this experiment the examination of the abstract roles of features was to be extended to include broader conceptual roles and not merely the physical functions of geographic features in determining location boundaries.

The second research question was *‘Do expert map readers integrate the abstract roles of remote but associated features within their schemas of what constitutes the* *outer extent of a locality?'* This question had been considered in Experiment 3a of this study but not studied in detail. Two of the 10 locations in the earlier experiment had possessed remote features but no differences had emerged between the Expert and Novice groups in their assessment of the significance of the remote features in defining the location extents. It had not been clear that the Expert group had integrated the remote features into their schemas of abstract roles.

The third research question was: '*Do expert map readers integrate the abstract roles of conceptual grouping features into their schemas of what constitutes the extent of the community boundaries?*' This question had not been researched in the earlier experiment. Of the three boundary determinants, geographical, remote features and grouping concepts, it was considered that the third was the most speculative. The concept of grouping had been included in the Davies (2009) study with mixed results. Participants had not included social cohesion such as 'people like us' or architectural similarities in terms of housing developments as key to establishing the boundaries of neighbourhood. However, they had rated place name as a high priority. Accordingly, grouped villages sharing similar core names might therefore be perceived as one integrated community.

6.2.4 Selection of the experimental research design

This section provides justification for selecting an experimental design closely resembling the design used in Experiment 3a and the rationale for the adopted modifications.

6.2.4.1 The Experimental Design Employed for Experiment 3a

The aim of Experiment 3a reported in the previous chapter had been to confirm that the Expert map readers employed cognitive schemas during a map comprehension task and if so, that the features within the schemas were grouped according to abstract roles.

A group of 20 Experts and a similar number of Novices had viewed map extracts of ten locations and then compared each location with two map excerpts one of which was visually similar and the other had physical features performing similar functional roles. Eye-gaze data and verbal protocols had been recorded throughout the experiment.

The experimental design had been both efficient and successful in providing confirmation of both the hypotheses.

6.2.4.2 Limitations of the Experimental Design Employed for Experiment 3a

The number of locations (10) used for the comparison tasks had limited the scope of boundary features that could be investigated. Eight of the locations had geographic features while only two had remote features. No locations with grouping features had been examined.

The use of verbal protocols had been illuminating but the requirement to articulate the features being considered during the map study demanded additional cognitive resources from the participants and may have been unrepresentative of a real world map comprehension task.

The *probe* slide had been presented for a pre-determined 15 seconds before automatically switching to the composite slide. This precluded measurement of individual study times for a selection controlled by each participant.

6.2.4.3 Proposed Modifications to the Original Experimental Design

The scope of the research was to be broadened by investigating the nature of the Experts' perceptions of the extent of location boundaries within three distinct categories: physical boundaries; remote features and; grouping concepts.

The number of map excerpts used for the location comparison tasks was to be increased from 10 in the original experiment to 32.

The requirement to provide verbal protocols was to be removed in order to increase the external validity of the study.

The length of time to complete the inspection of the probe slides would be determined by each participant to provide between-group comparisons of slide study times.

6.3 Method

This section outlines the method adopted for Experiment 3b based on the experimental design considerations discussed above. The section begins with information on the participants followed by details of the materials used throughout the experiment. The procedure is then provided together with a detailed description of the tasks undertaken by the participants. The experimental constraints and data analysis procedures are then addressed.

6.3.1 Participants

The participants were the same participants who completed Experiment 3a and are described in section 5.3.1 of Chapter 5.

6.3.2 Apparatus and materials

This section describes the experimental measures and the equipment employed for each test procedure. The rationale for each test is provided with the detailed test description.

6.3.2.1 Participant Consent Form and Map Experience Questionnaire

Both these forms had been completed for Experiment 3a and were not repeated for this study.

6.3.2.2 Probe Map Slides

A total of 32 UK town and village locations were selected from the Ordnance Survey, 1:50,000 Landranger series. As in the first part of the experiment they were drawn from the entire UK area and selected to ensure they did not represent one region for which experts may have had specialist knowledge and unfair advantage. The criteria for selection of 12 of these were the presence of distinct and adjacent geographic or man-made features which might have determined the extent of the boundaries of the urban development.

Thirteen of the locations had been selected for having a distinct but remote feature (railway station or road and river bridge incorporating the village name) which may have influenced the extents of the location boundaries. The remaining seven of the *probe* slides depicted locations which were paired with another location by a shared location name or formed part of a group of semantically associated villages sharing very similar names.

Map excerpts of each location representing approximately four square Kilometres or one square mile around the town or village were produced with the location sited at the geometric centre of the map. These were scaled as JPEG images to form a 22 x 18 centimetres screened image for the *probe* slides in the map comparison task.

The 32 slides were randomly allocated to two sets for counterbalanced presentations each containing an approximately equal number of the three categories: geographical boundaries; remote features and; grouping concepts.

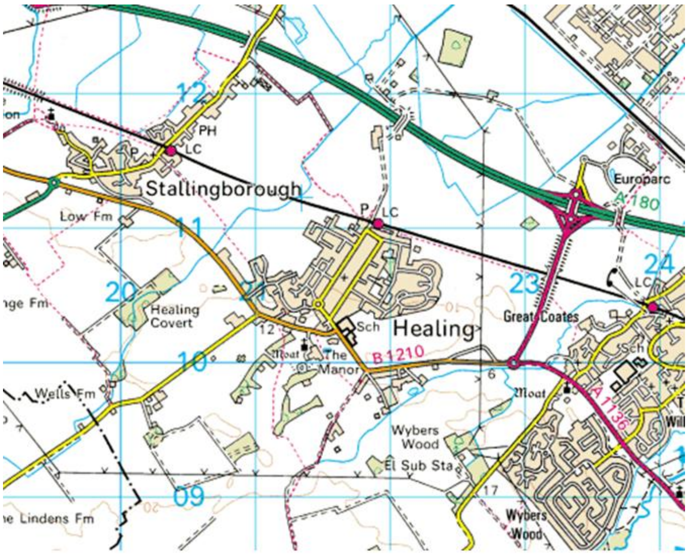


Figure 6.1 Example of a location with boundaries determined by physical features.

The town is constrained by the rail line to the North and partially by the road to the South

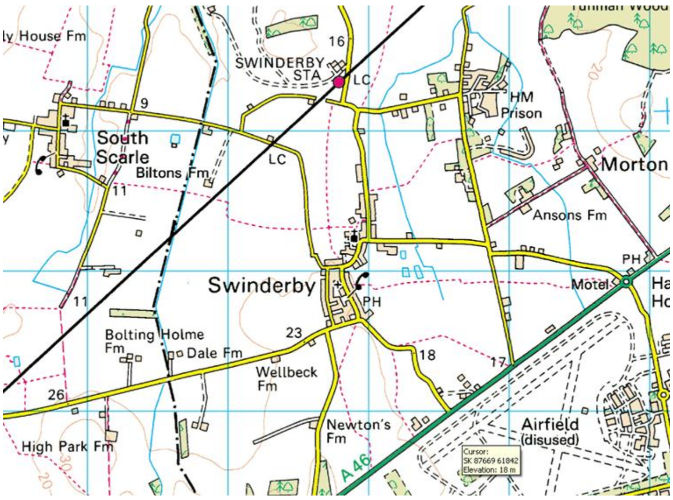


Figure 6.2 Example of a village location with a remote feature

The named station is remote to the North of the village

Figure 6.3 Example of a village having an adjacent pairing or grouping location

Great and Little Cheverell are separate villages linked by a common name

6.3.2.3 Combined Probe/Distractor/Target Slides

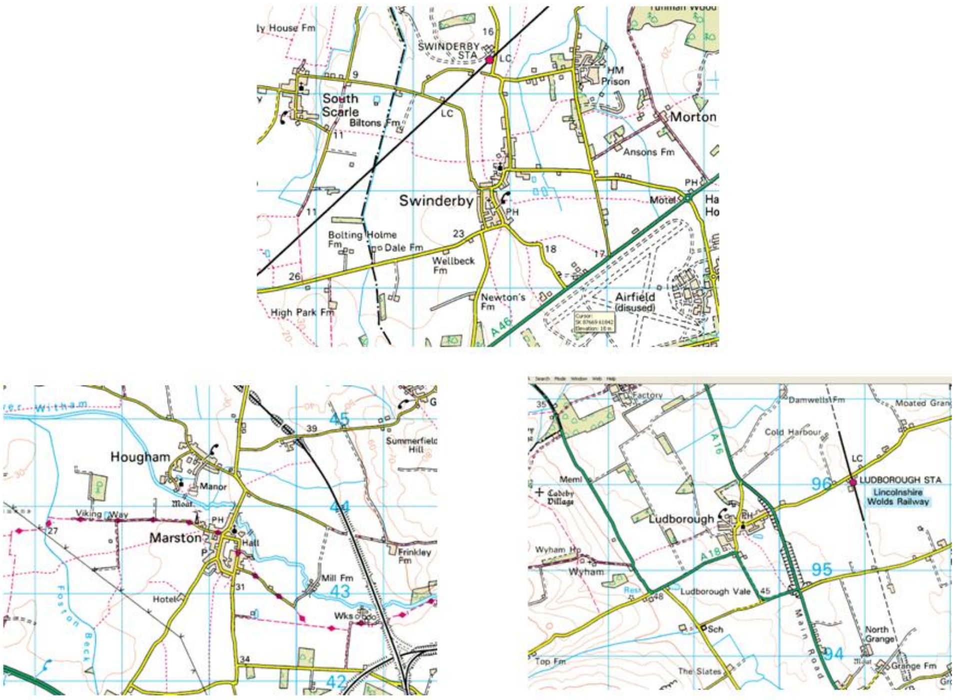
For each of the 32 *probe* slides a corresponding composite slide was constructed containing a half-size copy of the associated *probe* location sited above map extracts of two unfamiliar locations. As in the earlier experiment, one of these mapped locations had similarities with the *probe* location due to the spatial arrangement of adjacent features and constituted the *distractor* location. The remaining location portrayed a similar town or village as the *probe* location but which had boundary features performing similar abstract roles as those in the *probe* location. This map extract was the *target* location. Each of the three map extracts in the composite slide measured approximately 9 x 11 centimetres when displayed on the monitor.

The composite slides were designed to provide participants with the *probe* location as a reference with which to compare the *distractor* and *target* locations during comparison and selection for similarities of the boundary extents task.

A B

Figure6.4 Example of composite slide for a location with boundaries determined by physical features

(*The target location A has a boundary fully defined by the railway. Town B has developed either side of the railway*)



A B

Figure 6.5 Example of composite slide for location with remote feature

(*Village B is the target having a remote station. Village A has no station*)

A B

Figure 6.6 Example of composite slide for location with grouping feature

(Location A has a paired village and is the target. Location B is spatially similar)

6.3.2.4 The Experimental Task

The participants were required to study the first slide (*probe*) to identify which features determined the extent of the boundaries of the village or town located at the centre of the map extract. When the participants had completed their study, they selected the next slide with a mouse click. As in the earlier experiment this slide displayed the *probe* above a *distractor* (similar by feature patterns) and a *target* (similar by features performing the same abstract roles) both of which appeared in random order in either the left or right lower quadrant. The task had been selected to test the Experts' ability to identify the functions of the features which constituted the boundaries and to examine whether the functional properties or the visual similarities would be the criteria used by the Expert group to compare the locations.

6.3.2.5 Eye Tracker and Monitor

The Tobii X120 eye tracker was set up and operated as in Experiment 3a with the exception of the *probe* slide timings which were decided at the discretion of each participant.

6.3.2.6 Areas of Interest

The Tobii Studio software provided the facility to designate Areas of Interest (AoIs) on each of the map extracts and to construct a geometric shape surrounding each area.

These areas again contained features which constituted geographic boundaries, the extent of urban development or remote features which might have had some influence on the extent of the location boundary. For the slides depicting locations with grouping features these features were specifically designated for examination.

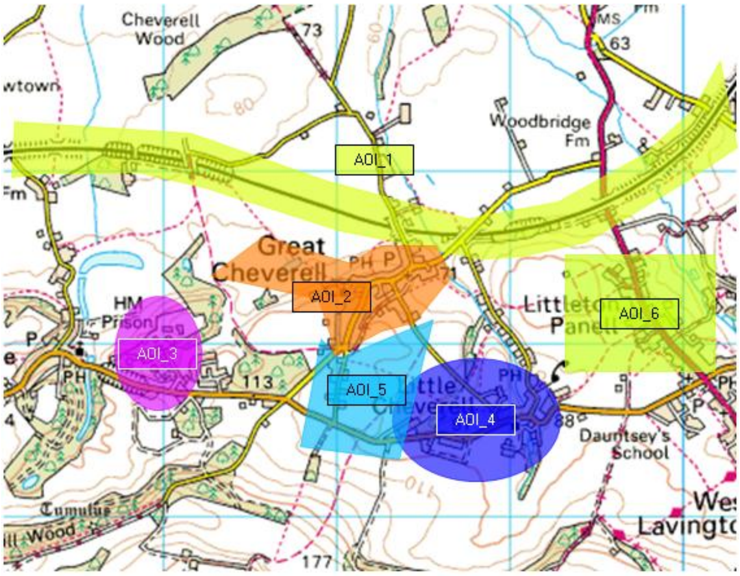
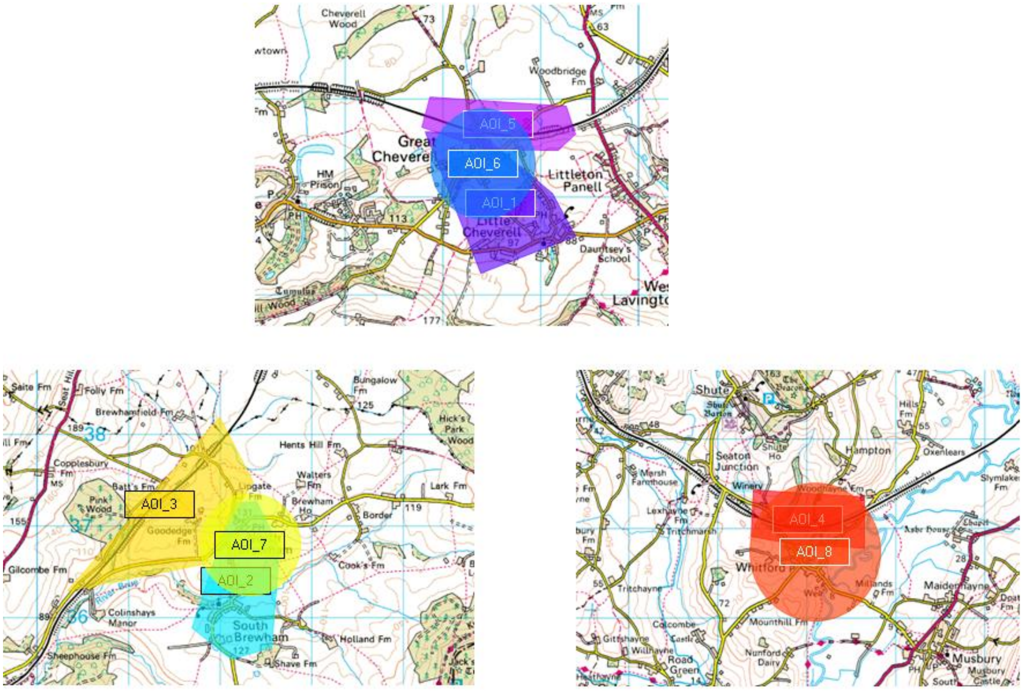


Figure 6.7 Designated Areas of Interest for probe location with grouping feature

(The Areas of Interest in figure 6.7 incorporate the grouping features - Great and Little Cheverell, the minor development between the villages, the railway to the North and adjacent village developments).



A B

Figure 6.8 Designated Areas of Interest for composite slide of location with grouping feature

(Areas of Interest in Figure 6.8 include each of the grouped villages, a composite area including both villages and the area between, the railway and the grouping features)

6.3.3 Procedure

This section provides a detailed description of the procedure employed to conduct the experiment. A brief overview of the procedure is followed by a description of the sequence of tests.

6.3.3.1 Overview of Procedure

Each participant remained at the workstation where they had completed the previous experiment and were briefed verbally on the procedures for viewing the next two sets of slides. The first of two counterbalanced sets of pre-programmed map slides was then selected in the Tobii operating programme.

Each test commenced with a calibration sequence followed by the instructions slide. The first slide and each subsequent slide were selected by the participants with a mouse click.

On completion of the first test the procedure was repeated for the second set of slides.

As in Experiment 3a, eye-gaze data was recorded throughout.

6.3.3.2 Detailed Sequence of Testing

Participants were seated at the workstation throughout the 25 minute experiment and completed the following procedures in sequence. The experimenter remained seated well clear on the left hand side with a laptop presentation of the monitor screen, the eye-tracking status panel and a reduced window indicating the user-camera display.

Experimental briefing. Participants were advised that they would be viewing two sets of slides similar to the set of slides they had viewed for Experiment 3a. The task was again to study the first slide of each pair to identify what features constituted the boundaries and to select which of the two locations in the accompanying slide was the most similar by the features which might determine the extent of its boundaries. For this part of the experiment participants chose how long they wished to study the *probe* slide before selecting the following slide with a mouse click.

The participants were also advised that they were no longer required to provide a commentary of their thought processes. They were then asked if they had any questions and when ready were instructed to start the calibration sequence.

Eye tracker calibration. Each participant was familiar with the eye tracker and was asked to resume a comfortable viewing position at a viewing distance of approximately 70 centimetres from the screen. The calibration sequence was selected on the monitor and initiated by each participant with a mouse click. A successful calibration was generally achieved on the first run.

Instruction slide The first slide of each test was the set of detailed instructions to ensure the briefing was consistent for all participants. It read:

> ***You are about to view some more excerpts taken from Ordnance Survey 1:50,000 maps. As before, in the centre of the picture is a town or village. You are asked to study this location for a short period after which you may left or right click the mouse and the screen will change to a slide containing a smaller picture of the location you have just studied above two pictures of different locations.***

> ***After comparing the two pictures with the reference location please select the picture, either A or B which in your opinion is most similar to the reference location in terms of the features which might determine the extent of its boundaries. Please answer as quickly and accurately as possible using the mouse to indicate your choice with a left-click for picture A and a right-click for picture B.***
>
> ***The next location will then appear automatically. This procedure will be repeated for fifteen separate locations.***
> ***For this part of the exercise you are not required to 'think aloud' as you study each of the pictures.***

Experimental test sequence The experiment supervisor started the slide presentation by selecting 'start recording' on the Tobii monitor. Each participant then studied the *probe* slide for a period varying between five and 25 seconds before selecting with a left or right mouse click the composite slide. When the participants had reached a decision on either the *target* or *distractor* location they selected their choice of A or B with a left or right click respectively. They repeated this sequence for the full set of slides working without interruptions and in silence. On completion the participants were tested with the counterbalanced test employing identical procedures.

All participants were thanked on completion of the experiment. Members of the Novice group were also paid £10 for participating.

6.3.4 Experimental design considerations

This section provides brief descriptions of the experimental constraints, methodological considerations and the procedures employed for data analysis.

6.3.4.1 Experimental Constraints

The length of the study was again determined by participant availability and possible fatigue effects since all participants had already completed the procedures for Experiment 3a. As a result the location stimuli were limited to 32 slides.

Since three categories of location were being examined, the moderately low numbers within each category resulted in sample sizes that were adequate but ideally would have been larger to increase the statistical power. While this effect had been partly offset by the robust number of participants in each group, the between-group effect sizes were expected to be small and the possibility of Type 2 errors could not be entirely ruled out.

6.3.4.2 Methodological Considerations

The monitoring of verbal protocols in Experiment 3a had provided important insights into the information processing procedures employed by experts while they completed the experimental task. There was therefore an argument for retaining the procedure for this part of the study.

Two factors were considered. Firstly the requirement to ‘think aloud’ required additional cognitive resources and was not the procedure normally employed by either the Expert or Novice groups during their quotidian duties. Also, an associated time penalty might be evident when the cognitive components of a task have to be articulated during its completion. In the interests of achieving increased task content and improving the external validity of the experiment, therefore, the protocol analysis was not included in the design.

The experimental task again explicitly instructed the participants to identify the features which determined the extent of locations while the experimental design concurrently tested for the use of implicit knowledge of the functions of the features during the comparison task. For this second part of the experiment, the expertise that the field surveyors had demonstrated earlier by their ability to identify the roles of physical features was to be extended to the more abstract roles of remote features and grouping concepts. Group differences would therefore be dependent on two factors. Firstly the Experts would be required to identify the functional nature of a remote feature or to assess that the grouping concept extended the location boundary. Secondly the Novices would be deemed not to possess this ability by virtue of their inexperience despite the possibility that a sociological or historical judgement might also lead them to the correct conclusion.

There was, therefore, an exploratory nature to the experiment and large group differences were not anticipated.

6.3.4.3 Data Analysis Procedures

The variables relating to group differences on the main experimental measures of group accuracy scores and study times were examined by a univariate analysis of variance (ANOVA). This was considered reliable within the following four assumptions: independence; random sampling; univariate normality and; homogeneity of variance.
The homogeneity of variance assumption was validated with a Levine's test. On all the main tests the Levine statistic was non-significant indicating that this assumption had not been violated. All ANOVA reports in the results section give the significance and F values for the univariate analyses conducted and all results give the significance for a two-tailed test.

Statistics from the eye-tracking data for fixation counts and fixation lengths were also separately analysed by ANOVA. In some cases the data provided low numerical values due to low activity levels within the Areas of Interest. As a result, the homogeneity of variance assumption was occasionally violated. Where the Levine's test was significant each of the relevant tests was independently examined using a t-test with a more stringent analysis for groups with non-equal variance. Where appropriate the revised significance value was reported.

Again, some of the composite slides had between five and 15 designated AoIs but the significant differences with p values below .05 and .01 were nevertheless reported without Bonnferoni corrections. If these results had reported main experimental effects, then values close to significance would have been considered unreliable. However, as they reported differences in group search activity within each slide, they provided cumulative evidence to support the Expert group's greater attention overall to geographical boundaries or remote features. These results are, therefore, reported uncorrected but with the added caution regarding their reliability.

6.3.5 Pilot study

The Pilot Study conducted for Experiment 3a had included the two counterbalanced tests which constituted the experimental task for Experiment 3b. This had provided an opportunity to validate the test procedures and assess the task timings.

Of the two Post-Graduate students who volunteered to be participants, one was a skilled but not expert map reader while the other was a genuine novice.

Both volunteers studied the *probe* slides for approximately 20 seconds and the composite slides for between 30 seconds and one minute. They chose the *distractor* slides for approximately three quarters of their choices confirming that they were predominately employing pattern recognition during their location comparisons. This result had been anticipated given the difficulty of the task and the lack of formal map reading expertise within the volunteers.

No changes were made to the experimental design following the Pilot study.

6.4 Results

The results are reported in seven sections. The first section reports the group accuracy scores for the comparison task of *probe* and *target* locations for the three location categories. The second section reports the study times and study patterns for the *probe* and composite slides obtained from the eye-gaze data. The third section provides details of the search activity within the designated Areas of Interest. The fourth section reports on the independent assessment of the experimental materials.

The fifth, sixth and seventh sections summarise the evidence from the experimental results to address each of the three research questions in turn.

6.4.1 Assessment of the extent of boundaries - accuracy scores

Experimental instrument: Tobii event recorder

Boundary comparison task Slides of all 32 locations had been presented to participants in two tests, counterbalanced to control for practice effects and test fatigue. Each test had contained an equal mix of the three location categories being examined. The results from both tests were combined for analysis.

Participants had compared *probe* location with the associated *target* or *distractor* locations in the composite slide for similarities of the location boundaries. The number of correct selections of *target* locations had been obtained from data recorded in the eye-tracker event recorder.

Accuracy scores The Expert and Novice groups did not differ significantly in performance accuracy when their combined scores for all location categories were compared. However, when group performances were examined within each of the three location categories, the Expert group was found to have selected the correct *target* location significantly more often (M = 7.0 SD = 1.2) than Novices (M = 5.8 SD = 1.8) in the ‘physical boundaries’ category $F(1, 38) = 5.68$, $p < .05$. Group performances, however, did not differ significantly in the task of matching *probe* and *target* locations in either the ‘remote features’ or ‘grouped villages’ categories. Since the number of test locations in each category were not identical group accuracy scores were also provided in percentage of *probe* slides correctly matched with the *target* locations (Table 6.1).

Location type	**Group Accuracy Scores**				**Sig**
	Experts		**Novices**		
	Mean (SD)	% (SD)	Mean (SD)	% (SD)	
Physical boundaries	7.0 (1.2)	58.3(10.1)	5.8 (1.8)	48.7(14.8)	*
Remote features	5.5 (1.7)	42.3(13.3)	6.0 (1.7)	46.1(13.0)	
Grouped villages	1.85 (.93)	26.4(13.3)	1.95 (1.1)	27.8(15.7)	

*Significant at the .05 level

Table 6.1 Group accuracy scores for *probe/target* matching by location category

The interaction between accuracy score and nature of the task The effect of task on Expert performance was examined by a repeated measures ANOVA where a significant interaction was evident for location category and group accuracy scores, $F(2,76) = 3.66$ $p <.05$.

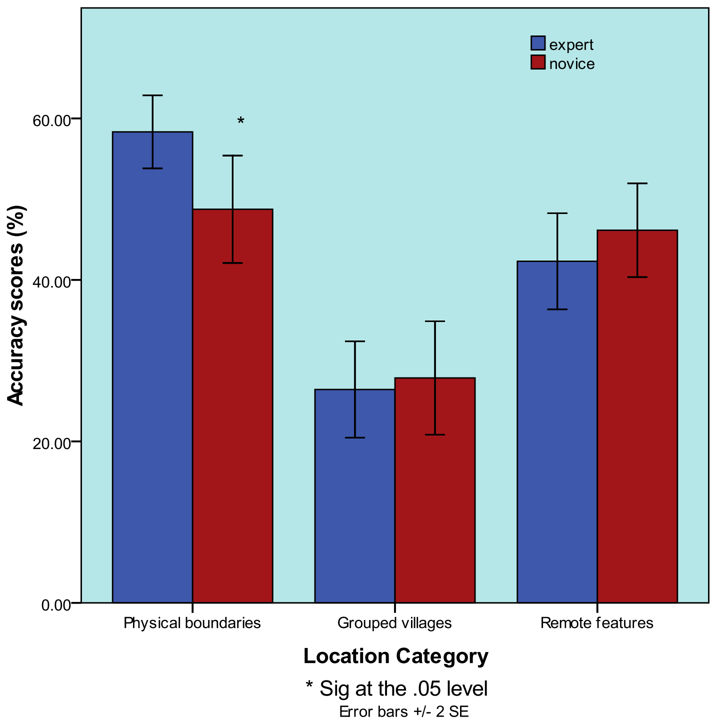


Figure 6.9 Group accuracy scores (%) for *probe / target* matching by location category

For the remote features task the Novices outperformed the Expert group, but not significantly so. Both groups performed almost equally poorly for the grouped village category, while Experts were significantly better at matching the physical boundaries of the *probe* location with the *target.*

6.4.2 Study times and study patterns

Experimental instrument: Tobii eye-gaze data

Study times In this experimental task, viewing times for the initial *probe* slide were determined by each participant. Again it had been anticipated that Experts would have reduced study times for both the initial study of the *probe* slides and also for the subsequent matching of *probe* and *target* task. However, the Expert group were not significantly quicker when studying the *probe* slides nor when selecting the *target* location in the associated *probe / distractor / target* slide across all location categories (Table 6.2).

Study Task	Group study times		Sig
	Experts Mean (SD)	**Novices** Mean (SD)	
Probe slides	11.2 (5.3)	9.6 (2.5)	ns
Probe/distractor/target slides	17.6 (9.8)	13.2 (5.7)	ns

Table 6.2 Group study times for *probe* slides and combined *probe/distractor/target* slides

A more detailed inspection of study times in a repeated measures ANOVA including participant age as a covariant revealed a non significant interaction, F (1,37) = .097, p=.757 , between age and location category for study times of the *probe* slides and for the subsequent *probe/ distractor/ target* slides.

Mean study times for the experts for all Location categories were consistently longer than for novices but the group differences did not approach significance (Table 6.3).

Location Category	**Group**	***Probe* study time (SD)**	***Probe/distractor/target* study times (SD)**
Physical boundaries	Experts	11.06 (5.14)	17.57 (10.43)
	Novices	9.78 (2.68)	13.13 (5.70)
Grouped villages	Experts	11.52 (6.22)	17.44 (11.7)
	Novices	9.73 (2.4)	12.76 (5.57)
Remote features	Experts	11.07 (5.36)	17.02 (11.21)
	Novices	9.34 (2.56)	13.23 (5.76)

Table 6.3 Study times for *probe* and *probe/distractor/target* slides for each location category

Study Patterns When studying the *probe* slides, the Expert group again concentrated more of their attention within the urban confines of each location than the Novices. Observation times within the built up areas of *probe* locations were compared with overall study times and expressed as a percentage of study times. Inspection by ANOVA showed that Experts percentages (M = 43.3 SD = 14.9) were significantly higher, F (1, 38) = 5.51, p <.05 than Novices (M = 32.9 SD = 13.0) (Table 6.4).

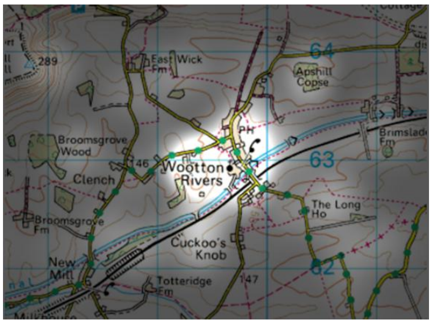
	Urban area group study times		Sig.
	Experts Mean (SD)	**Novices** Mean (SD)	
Percentage of study time	43.3 (14.9)	32.9 (13)	*

* Sig at the .05 level

Table 6.4 Probe slides-Group study times for urban areas

Examination of the gaze opacity plots, where cumulative gaze lengths were again represented by least opacity, showed that Novices scan patterns were less focused on the urban confines than the Expert group. The plots also showed evidence of increased search activity outside the immediate village environs by the Novice group (Figure 6.10). However, the effect was less marked than that observed in slides from Experiment 3a of this study.

Expert study pattern



Novice study pattern

Figure 6.10 Group differences for study patterns in *probe* slides

During the study times of the *probe/target/distractor* slides, Experts again spent marginally longer attending to the urban confines of all three locations but the result was not significant (Table 6.5).

Location Map Inset	Urban Areas group study times – Percentages		
	Experts –Mean (SD)	**Novices** – Mean (SD)	Sig
Probe	14.6 (5.7)	13.7 (6.5)	-
Target	18.1 (6.2)	16.8 (5.6)	-
Distracter	19.3 (6.5)	19.2 (6.4)	-
Totals	52.0 (15.7)	49.8 (16.0)	-

Table 6.5 *Probe/target/distractor* Slides - Group study times (percentages) for Urban Areas

6.4.3 Search activity in designated Areas of Interest

Experimental instrument: Tobii eye-gaze data

Fixation counts and fixation times within designated Areas of Interest Eye-gaze data for each participant was again evaluated by measuring fixation counts (number of fixations above 100ms within a 30 pixel radius) and observation length (cumulative time in seconds) within each designated Area of Interest. Group means for each measurement were then compared. Groups with significantly higher scores for either of the two measurements are reported in Table 6.6 as follows:

*/** Fixation counts significant at the .05/.01 level.
+/++ Observation length significant at the .05/.01 level
Eye gaze data for all slides is collated by category of location boundary.

Physical Boundaries category

Slide	Map location	AoI	Description	Expert	Novice
1	Probe (Large)	1	Rail (Boundary)	*/++	
		2	Urban Confines	*/+	
2	Distractor	13	High Ground to East	*/+	
	Distractor	12	Rail Boundary		+
5	Probe (Large)	-	-		
6		-	-		
13	Probe (Large)	3	Urban Confines	+	
14	Distractor	8	Distractor slide total	*	
15	Probe (Large)	3	Urban Confines	*	
		1	River Valley	+	
		6	River Boundary	++	
19	Probe (Large)	2	Urban Confines	*/+	
		3	River Boundary	+	
		4	Extended Urban Confines	+	
20	Distractor	8	Urban Confines		*
33	Probe (Large)	1	Urban Confines	+	
34	Probe	1	Urban Confines	+	
	Distractor	2	Urban Confines	+	
	Target	3	Urban Confines	+	
	Target	5	Lake	+	
37	Probe (Large)	5	Wood to East-non boundary		**/++
38		-	-		
41	Probe (Large)	2	Adjacent village -non boundary		**/++
42	Target	11	Clear area beyond rail boundary	*/+	
	Target	12	Rail boundary	+	
43	Probe (Large)	3	Clear area beyond rail boundary	**/++	
44	Probe	3	Clear area beyond road boundary	*/+	
47	Probe (Large)	2	Urban Confines	+	
48	Target	7	Urban Confines	*/++	
49	Probe (Large)	4	Place name		**/++
		9	Place name		**/++
		7	Feature Description - script		+
50	Distractor	2	Urban Confines	+	
	Probe	11	Road Boundary	*/+	
63		-	-		
64	Probe	2	Urban Confines	*	
	Probe	3	Extended Urban Confines	*	
	Target	4	Urban Confines	**	
	Distractor	8	Urban Confines	*	
	Target	11	Extended Urban Confines	**/++	

Table 6.6 Physical Boundaries category- group differences in fixation counts and observation lengths in AoIs

Within the Physical Boundary category, the Expert group had either higher fixation scores or greater observation lengths than Novices when studying nine areas of interest relating to physical features.

Experts also studied the urban confines in both the *probe* and composite slides more than Novices with higher fixations or gaze lengths on 17 occasions compared to one instance when the Novices recorded more fixations on the urban confines of a *distractor* location.

Novices again focused on non-boundary features such as woods or place names more often than Experts scoring higher gaze-data activity on five non-boundary related features.

Grouped Villages category

Slide	Map location	AoI	Description	Expert	Novice
7	Probe (Large)	6	Wood to W – non boundary		**/++
		7	Urban Confines	*/+	
8	Target	3	Urban Confines	+	
9	Probe (Large)	2	Urban Confines	+	
10		-	-		
17		-	-		
18	Probe	1	High Ground to SE	+	
	Probe	2	High Ground to W		**/++
	Target	7	Grouping Feature		+
23	Probe (Large)	1	Urban Confines	*/+	
		4	Wood to W –non boundary		+
		5	Distant Dual Carriageway – non boundary		**/++
24		-	-		
27		-	-		
28	Target	9	Grouping Feature	*	
	Distractor	14	Main road through village	*	
	Distractor	15	Urban Confines	*	
45	Probe (Large)	3	Urban Confines	**/++	
46	Target	10	Urban Confines	*	
57	Probe (Large)	6	Urban Confines	*/+	
58	Probe	3	Urban Confines	*	
	Target	5	Remote Feature	*	

Table 6.7 Grouped Villages category-group differences in fixation times and observation lengths in AoIs

Within the Grouped Villages category of locations the Experts again appeared to concentrate their attention on the urban confines of each location studied.

Remote Features category

Slide	Map location	AoI	Description	Expert	Novice
3	Probe (Large)	3	Extended Urban Confines	++	
		4	Dual Carriageway-non boundary		*/++
		8	Urban Confines	+	
4	Probe	2	Rail stn-Remote feature	*	
11	Probe (Large)	4	Urban Confines	+	
12	Target	5	Remote Feature		*
21	Probe (Large)	1	Remote Feature	*/+	
		3	Urban Confines	*	
22	Distractor	11	Adjacent Airfield (Possible boundary)	*	
25		-	-		
26		-	-		
29	Probe (Large)	1	Water feature & County Boundary		*
		4	River Boundary	+	
30	Target	4	Rail stn- Remote Feature	*	
31	Probe (Large)	3	Urban Confines	++	
		6	Adjacent spring - non boundary	*	
32		-	-		
35	Probe (Large)	1	Urban Confines	+	
		2	Remote Feature		*
36		-	-		
39		-	-		
40	Distractor	7	Remote Rail	*/+	
	Target	10	Remote rail	*	
	Target	11	River boundary	*/+	
51		-	-		
52	Target	3	Urban Confines	*	
53	Probe(Large)	3	Adjacent Airfield		+
54		-	-		
55	Probe (Large)	5	Rail cutting to E		++
		8	Farm		+
		9	Rail cutting to NE		*/+
56		-	-		
59	Probe (Large)	5	Feature description - script		*
		6	Water feature		*
60		-	-		
61	Probe (Large)	1	Urban Confines	+	
		5	Distant village		+
		6	Distant wood		*/+
62	Target	5	Urban Confines	+	
	Target	7	Distant village to N	*/+	

Table 6.8 Remote Features category-group differences in fixation times and observation lengths for Areas of Interest

On 10 occasions the Experts scored higher counts of fixations or attention times within these areas than the Novices.

Neither group appeared to pay more attention to the grouping features, with the Experts surpassing the Novices fixation counts on one of the *target* slides (28) and the Novices studying a grouping feature longer in another *target* slide (18). In two of the *probe* slides Novices studied non-boundary features significantly longer than the Experts.

The remote features incorporated within the *probe* and *target* locations included rail stations, parks, river bridges or commons sharing the same name as the location being considered. In each case the remote feature might have defined an outer extent of the village boundary.

Eye-gaze data revealed that Experts attention was more focused than Novices within the Area of Interest surrounding these remote features on five of the 13 presented slides. However, on two slides the Novices recorded higher fixation activity on the remote features than Experts.

The groups again differed in their attention to the urban confines of the locations with Experts employing higher gaze activity than Novices within these areas on ten of the locations presented.

Group differences in study patterns were also evident in four features which had not been identified as relevant to identifying location boundaries. Novices studied five non-boundary features, such as rail cuttings and woods, significantly longer than Experts. While the Expert group paid greater attention than the Novice group to a spring and a non-relevant village in two of the slides.

6.4.4 Independent verification of map materials

The map extracts had been selected by the experimenter in close consultation with the research department at Ordnance Survey. In every case the *probe* slide contained features which experienced map readers might be expected to consider when deciding the outer extents of locations. However, while the results for the Physical Boundaries category had been consistent with those obtained in Experiment 3a, both groups chose the correct *target* location for only 25% of the slides in the Grouped Villages category and only approximately 40% of their choices in the Remote Feature slides.

An independent assessment of the map materials was, therefore, conducted to verify that the extents of the selected locations were determined by the features identified in the original selection of materials. Two experienced map researchers employed by Ordnance Survey were presented with a full set of the *probe* locations with instructions to identify and prioritise three features which determined the extent of the location boundaries for each of the *probe* slides and to mark these on each of their printed paper maps. The independent assessors were not required to complete the *probe/target/distractor* location comparison exercise and there was no time limit for completion of the task.

Predictably, both assessors correctly identified the physical features in the Physical Boundary locations and nominated a geographic or man-made feature in each of their three prioritised selections. This confirmed that for a comparison task in which similarities of boundary features were to be compared, the assessors would have processed the physical features in the *probe* locations prior to inspection of the *target* and *distractor* slides as hypothesised.

For the Remote Feature and Grouped Villages categories, however, a less consistent pattern emerged. For the Remote Feature slides the first assessor chose to prioritise the remote feature as being the most important consideration in just over a third of his choices, while the second assessor prioritised it for approximately half. In the remaining cases, where the remote feature was nominated as the second or third most relevant boundary feature, a physical boundary had been selected as a more significant boundary marker (Table 6.9). The number of times the remote feature was included in any of the assessors' first three choices was also calculated and showed that both evaluators had fully considered the concept that an isolated but related feature might determine the outer extent of location boundaries. The first assessor included the remote feature in two thirds of his prioritised selections while the second assessor included it as a boundary consideration for every location.

Mean scores for prioritising the remote features were calculated by applying reverse weighting to the order of priority assigned by each assessor. Assessor 1 gave a lower priority ($M = 1.69$, $SD = 1.25$) to remote features than Assessor 2 ($M = 2.38$, $SD = .77$) but the performances did not differ significantly ($t(24) = -1.7$, $p = .102$).

Assessor	Remote Features				
	Assigned order of relevance (%)			Inclusion in first three choices (%)	Weighted scores (SDs)
	One	Two	Three		
One	38.5	6.5	23.1	68.1	1.69 (1.25)
Two	53.8	30.7	15.5	100	2.38 (.77)

Table 6.9 Prioritisation of remote features by independent assessors

Therefore, although the remote features had been identified and evaluated in a high number of the assessors' first three choices, the frequency with which it had been selected as the most important feature averaged at just below 50%. Interestingly, this result closely equated with the group scores for accurately matching the remote feature *probe* and *target* locations in the main experiment.

When the same analysis was conducted for the Grouped Villages category, a similar pattern emerged. Both assessors included the grouping concept as relevant to the boundary identification exercise in well above half their first three choices. However, each assessor only prioritised the grouping factor as the most important boundary consideration in just under a third of their choices (Table 6.10). Once again, this lower figure closely matched the accuracy scores for both the Expert and the Novice groups in the location comparison task.

Assessor	Grouped Village Features				
	Assigned order of relevance (%)			Inclusion in first three choices (%)	Weighted Scores (SDs)
	One	Two	Three		
One	28.6	14.3	42.8	85.7	1.57 (1.2)
Two	28.6	14.3	14.3	57.2	1.28 (1.3)

Table 6.10 Prioritisation of grouping features by independent assessors

Comparison of the weighted scores again confirmed that the assessors had not differed significantly ($t(12) = .423$, $p = .68$) in their evaluation of the contribution of grouping concepts in defining location boundaries.

The analysis thus provided confirmation that the remote features and the grouping concepts were valid elements in any consideration of possible location boundaries. However, both these categories were affected by individual variability in assessment of their relative importance. Where the assessors gave priority to the remote or grouping feature in well above half their evaluations when three features were included, this result was far lower when only the primary choice was examined. Since the Expert and Novice experimental groups had achieved accuracy scores which closely matched the percentage scores for features prioritised as the main feature by the assessors, it was possible that the experimental participants had conducted their comparison task employing non-physical features only when they assessed them to be the primary feature for consideration.

In short, the remote feature and grouped village concepts were shown to be clearly relevant for a boundary identification task, but where the experimental map extracts had been originally selected as having these concepts as *the* defining boundary feature, in a number of cases these features may have been only *a* defining feature. As a result, it was possible that other features may have been employed and assigned a higher priority during the location comparison tasks.

6.4.5 Evidence to support the first research question

Research Question 1: *Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping geographic features according to abstract roles?*

Of the 12 locations with boundaries determined by physical features, the Expert group had correctly selected the *target* slides for more than half of these, despite the visual similarities presented in the *distractor* slides. This had been a significantly higher number than the Novice group. Since the location in each of the *target* slides was similarly constrained to the *probe* location by the roles of the physical features this demonstrated that the Experts had judged location extents to be based on the abstract roles of features. It also supported the proposition that features contained within the prototypical configurations of the Experts' cognitive schemas may well have been processed according to their abstract roles.

The eye-gaze data indicated that Experts had a higher number of fixations or longer observation times on physical features such as railways and rivers than the Novices. For the *probe* slides the Experts had also spent significantly more of their search time within the urban confines of the location. If the Experts' search times outside the urban confines had been correspondingly less than the Novices, but their attention to physical features had been greater, this suggested a sharply focused concentration on physical features. Again, since these features had been selected for the abstract roles they fulfilled in establishing the boundaries, this provided further evidence of the processing of features according to their abstract roles.

6.4.6 Evidence to support the second research question

Research Question 2: *Do expert map readers integrate the abstract roles of remote but associated features within their schemas of what constitutes the outer extent of a locality?*

Thirteen of the *probe* locations had contained villages with remote features. The Expert group chose to match these locations with *target* locations also having a similar associated feature for 42 % of their choices. This had been lower than the Novices 46% but not significantly so.

There was therefore some evidence that despite the draw of spatial configuration similarities in the *distractor* slides, some participants appeared to be taking account of the role of the remote features in determining the outer extent of the location boundaries. However, there was no evidence to suggest that Experts differed from the Novices in integrating the abstract roles of remote features into their cognitive schemas for boundary extents.

Examination of the eye-gaze data showed that the Expert group had higher fixations or gaze lengths than Novices on the relevant remote features on five occasions. Conversely the Novices had higher gaze activity than the Expert group on the remote features portrayed in two different slides. This result indicated that the remote features were being processed by participants from both groups but they did not appear to contribute to consistent selections of the *target* location in the comparison task. Therefore there was no reliable indication that the Experts had processed the abstract roles of the remote features within their cognitive schemas any more than the Novices had.

6.4.7 Evidence to support the third research question

Research Question 3: *Do expert map readers integrate the abstract roles of conceptual grouping features into their schemas of what constitutes the extent of the community boundaries?*

Across the counterbalanced tests, seven of the *probe* locations had contained villages with conceptual grouping features. Participants from both groups averaged less than two correct *probe* and *target* matches for these villages. Although the Novices had a marginally higher percentage of correct responses (28%) they were not significantly higher than the Experts (26%). On these figures it appeared that neither Experts nor Novices had perceived the paired or grouped villages as a group when comparing the *probe* locations with similarly paired villages in the *target* slide.

The eye-gaze data revealed that the Novice group had recorded significantly longer observation times on the grouping feature in one of the *target* slides while the Expert group had more fixations than the novices on a paired village in another *target* slide.

These results suggested that the grouping features had been observed but not employed for the location comparisons. The findings were further confirmation that the groups had not differed significantly in their attention to the grouping features. Accordingly, the results did not provide any evidence that the Experts had consistently integrated the grouping concepts into their cognitive schemas.

6.5 Discussion

This section revisits some brief observations on the characteristics of the two groups of participants outlined earlier in Experiment 3a. The results as they relate to each of the three research questions are then discussed.

6.5.1 Characteristics of the participants

The participants for this experiment were those who also completed the earlier Experiment 3a. The Expert group comprised the same 20 professional field surveyors employed by Ordnance Survey.

As surveyors their main duties involved updating changes in the landscape of selected areas with the OS held mapping data. This activity no longer included the recording of place names and place extents as a designated task but most of the group had experience of this exercise either when it had been a formal requirement or more recently on an informal basis when completing their surveys (Davies 2009). As a group, therefore, the surveyors were well qualified to judge which features constituted the extents of a location based on their considerable experience and surveying expertise.

Participants in the Novice group were students in the Natural Geography Department at the University of Sussex and were selected because they were competent contour map users. These participants would be expected to identify accurately geographical and man-made features in the map excerpts and to assess the extents of the locations based on personal judgements of feature relevance.

The two groups differed in average ages and ratio of males to females and the possible age and gender effects which may have arisen were discussed fully in the earlier experiment reported in Chapter 5 (Para 5.5.1).

6.5.2 Discussion of the first research question

Research Question 1: Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping geographic features according to abstract roles?

This research question had been examined in Experiment 3a where the evidence from the eye tracker and the protocol analysis had confirmed that the Experts had indeed integrated the abstract roles of features into their cognitive schemas during the location comparison tasks. There was, however, a requirement to verify this finding within this experimental design for the geographic and physical features before evaluating the participants at the more demanding tasks of assessing the relevance of the remote features and grouping concepts addressed by research questions 2 and 3.

The accuracy scores for the matching of *probe* and *target* were closely aligned with those obtained in the earlier experiment. Again the Experts had significantly outperformed the Novices in selecting the physical and geographic features more consistently than the spatial similarities when comparing the extents of the *probe* and *target* locations. This had occurred in spite of the introduction of more man-made features, such as railways, as outer boundaries. These boundary features could be considered as less definitive than the naturally formed physical boundaries which had populated the slides in Experiment 3a and would have constituted a more demanding experimental task.

The eye-gaze data revealed that the Experts had attended to the man-made features and the physical boundaries more than the Novices during their map inspections confirming that they identified the functions the roads and railways were performing as boundaries. In the inspections of the *probe* slides the Experts had once again spent less time and fewer fixations than the Novices outside the immediate urban confines despite paying more attention to the surrounding physical features. The more focused study of relevant features by the Experts was indicative of the more efficient information processing associated with the use of cognitive schemas.

Although there was no confirmation of which features the Experts had studied from verbal protocols, as in the earlier study, the similarities in accuracy scores and search patterns from the eye-gaze data were reliable indicators that the Experts had again integrated the physical and geographical features into their schemas during the map study periods.

Of course it could be argued that the accuracy scores of the Experts were, at 58%, only just above chance since only two choices, the *target* and the *distractor*, had been available.

Three important factors counter this argument. Firstly, the visual similarities produced in the *distractor* slides were designed to be persuasive. Interpretation of the abstract roles of the physical features required additional cognitive processing. Choice of the *target* slide therefore required conscious decision making and was not the default option. All choices away from the *distractor* slide thus represented an appreciation of the abstract roles.

Secondly, the study times for the Experts were expected to be shorter than the Novices but as discussed later in this section, they were not. The Experts were therefore making deliberate judgements and not merely unconsidered choices normally associated with guessing.

Thirdly, the accuracy scores for identifying the roles of physical features for the experienced group in this experiment mirrored the Experts' scores for the previous experiment. In both cases the Experts had scored significantly more correct responses than the Novices and consistently in the direction of the research hypothesis.

What the results did show, however, was that the Experts had not been entirely consistent in employing the abstract roles of features as their only criteria. Had that been the case the experts would have scored 100% in selections of the *target* slide. As in the previous experiment, therefore the Experts had included comparisons based on spatial configuration similarities for at least some of their choices.

The study times for the Experts had not differed significantly from the Novices for either the *probe* or the combined slides although for both tasks the Experts' times had been slightly longer. This result was counter-intuitive since the Experts' use of schemas should have contributed to more efficient and therefore faster information processing.

The possibility that the greater ages of the Expert group might have increased their performance times due to age effects had been considered. The inclusion of participant ages as a covariant in the analysis of study times had however not revealed an interaction due to age. One possibility considered was that age effects and speed of processing advantages due to expertise might have effectively neutralised any measurable significant values of either. More likely, however, the Experts had processed the necessary information quicker than the Novices but had adopted a more thorough approach to the experimental task and had explored more options before making their considered judgement. This conclusion was favoured in Experiment 3a where similar study time variations had been observed.

Conclusion With a larger set of stimuli and a more demanding boundary identification task than those employed for Experiment 3a, the Experts again favoured the abstract roles of features over pattern recognition similarities in judging the extent of boundaries. Eye-gaze data provided evidence that the Experts employed cognitive schemas in which features appeared to have been integrated according to their abstract roles during the location comparison task.

6.5.3 Discussion of the second research question

Research Question 2: *Do expert map readers integrate the abstract roles of remote but associated features within their schemas of what constitutes the outer extent of a locality?*

In Experiment 3a the results for the two locations with remote features were inconclusive. For a remote rail station only 30% of both groups of participants included it in their interpretation of the boundary extents. For a remote and named river bridge both groups again had identical scores. For this feature, however, 70% of participants matched the location with a *target* location having a similar remote feature. In both cases map-reading expertise had not appeared to influence the decision making.

This experiment therefore had attempted to clarify the earlier results. Thirteen locations with remote features such as bridges and rail stations but now including meadows, parks and historic buildings had been included in the counterbalanced tests.

All remote features had shared the name of the subject location and had ranged from approximately 500 to 1000 metres from the centre of the location. The results in this experiment had again been inconclusive. Just over 40% of the Experts' *target* choices had been influenced by the remote feature, a similar result to the Novices.

The question that this result had failed to answer was therefore: If the Experts identified the roles of abstract features in determining boundaries, why were remote features not consistently included in this assessment?

Five possible interpretations of the results are now examined. The first possibility was that the Experts may not have processed the remote features sufficiently well to integrate them into their schemas. This explanation was relatively easily dismissed by inspection of the eye-gaze data. Despite the Experts attending to areas outside the restricted urban developments less than the Novices they had nevertheless recorded higher gaze activity on remote features on five separate slides. This was in comparison to the Novices paying greater attention to the remote features on two different slides. Participants from both groups had therefore clearly observed the remote features with the Experts demonstrating more consistent attention to the remote features than the Novices.

Secondly, the Experts may have misinterpreted the requirements of the experimental task. They might have regarded the instruction to identify ‘features that determine the extents of the location’ to mean the extents of only the immediate urban confines. In this case they may have identified the remote features but consciously excluded their possible influence in extending boundaries. In an attempt to avoid this possibility the term ‘location’ had been employed at the outset in all the written and verbal task instructions. The term ‘location’ had been carefully selected as an abstract place noun which operated at a meta-level for place definitions since it did not constrain any physical or spatial properties (Agarwal 2007). The lack of constraint implicit in the term location might therefore be considered as a concept familiar to the Expert group. In addition the term location had not constrained the Experts in their examination and ultimate selection of physical features beyond the urban confines as relevant boundary features in the other categories. Nevertheless, task misinterpretation remained a possibility.

The third explanation was that the Experts had developed cognitive schemas in which only one or two categories of remote features were considered as possible extensions to boundaries, and this had skewed the results. Detailed inspection of the accuracy scores showed that this was not the case. Remote bridges had been included in the comparison tasks as often as they had been excluded. A similar pattern was evident for remote stations. Likewise there was no identifiable consistency in decisions of exclusivity for other classes of remote feature. Undue selectivity of remote features by type or function had not appeared to contribute to the Experts’ poor performance in this category.

The fourth interpretation related to the nature of expertise possessed by the field surveyors. In Chapter 2, the importance of domain-specific knowledge and task familiarity in defining expertise were recurring themes (Shantau 1992). Defining locations by the physical features that constitute the boundaries could be considered a familiar activity at which the surveyors’ expertise would be expected to contribute to expert performance. However, classifying place names and place extents was no longer a formal task undertaken by Ordnance Survey staff. Where judgements of location boundaries incorporated sociological or community concepts this might have involved a departure from the expertise currently held by the field surveyors. This knowledge may have been held and indeed employed previously but the lack of practice in making these judgements might have reduced this component of the Surveyors’ current expertise.

Also relevant here was the introduction of fuzziness of concepts. For instance what distance constitutes the outer distance of a remote feature's influence on boundary extents? Do these distances vary by feature type? Such considerations would be particularly relevant if the cognitive schemas of the Expert group did not contain prototypical notions of these parameters. The results indicated that the expertise employed by the surveyors had not provided any advantages in their judgements of the roles of remote features.

The final consideration arose from the independent analysis of the map extracts. Where remote features were evaluated as being the most important feature, it was evident that participants from both groups based their comparisons on these features. However when the remote feature was assigned a lower priority it was possible that location comparisons were conducted incorporating physical features in addition to the remote feature. In this event, the remote features may have been processed as relevant but not sufficiently so to influence the accuracy scores for selection of the *target* location in the comparison task.

Conclusions There was evidence that the Expert group observed and processed the remote features which might have constituted the extent of the location boundaries. However, in selecting *target* locations, the Experts had not made comparisons according to the abstract roles of the remote features. Both Experts and Novices chose the *target* slide on fewer than half their selections. Although misinterpretation of the task may have caused the poor result it was considered more likely that the nature of expertise currently held by the field surveyors had not conferred any advantages for the experimental task.

6.5.4. Discussion of the third research question

Research Question 3: *Do expert map readers integrate the abstract roles of conceptual grouping features into their schemas of what constitutes the extent of the community boundaries?*

The accuracy scores for villages with grouping concepts as boundary determinants were the lowest for all three of the researched scenarios. Less than a third of the villages, which might have been considered to form an integrated pair or trio, were matched with a similarly grouped set of locations by participants from both groups. Experts therefore, had not perceived the grouped locations as single entities as had been anticipated. Some possible explanations are now discussed.

The first two considerations were similar to those examined in the previous section and were: Did the participants fail to process the grouping features or did they misinterpret the task requirements? Again there was evidence from the eye-gaze data that on two occasions the grouping features were being attended to significantly more often by one of the groups. This occurred once for the Experts and once for the Novice group. In the remainder of the seven grouped locations there was reliable evidence of visual attention which did not however generate group differences. As in the remote features task the suggestion that the participants had not observed the relevant features was again not supported by the evidence from the eye-gaze data.

Had the participants interpreted the word location as referring to a single village? This concern was more relevant in this task than it had been for the remote feature exercise. As already noted, the term ‘location’ had no formal constraints on physical or spatial properties but, importantly, there were also no semantic properties of the word which suggested automatic grouping of sub-ordinate localities. The word ‘location’ had been carefully selected for its neutrality to avoid inducing experimental effects but it may have required more precise qualification for this element of the experimental task. Possibly the concept of community had required to be formally stated in the experiment instructions in order to trigger the relevance of grouping concepts among the Experts. Also, it was relevant that the locations studied within the other two experimental categories had all incorporated single villages or towns and the requirement to identify grouping concepts was at variance with the remainder of the experimental task. This may have had a priming effect on participants as they studied the locations in the grouping concepts category.

The third explanation is considered the most relevant and again concerns the nature of information possessed by expert map readers. The grouping features presented in the probe slides had contained pairs by size (Catwick and Little Catwick), by relative altitude (Upper Chute and Lower Chute), by geographical valley location (Brixton Devrill and Monkton Devrill), by distinguishing feature (Brightwalton and Brighwalton Green), by cardinal description (East & West Lambourne) and by adjacent and relevant geographical features defining locations (West Stour, East Stour and Stour Provost). As can readily be seen none of the grouping concepts required detailed understanding of their derivations in order to make a judgement that they might constitute associations of either an administrative, cultural or communal nature.

It could be argued that a study of say Catwick and Little Catwick would be enhanced by an understanding of the factors that might have determined why Little Catwick developed as a separate area rather than as a part of an evolving *Greater* Catwick. Similarly studying Brixton Deverill and Monkton Deverill with the knowledge that they both reside in the Deverill valley provides a more comprehensive picture of the map being studied. More illuminating still might be the knowledge that the word Deverill is derived from old English for *diving rill* (or disappearing stream) which might provide an even clearer perception of the features which each location might share. However, does such information contribute to expertise in judging the extent of a location's boundaries? Certainly the absence of group differences was a good indication that the Experts had no advantages at this task over the Novices. This may of course have been due to both groups recognising only the superficial similarities in which case the Experts would perform no better than the Novices. More likely, however, the Expert group possessed a greater understanding of the historical and cultural factors which were implied by the shared names of the independent locations, but this constituted expertise which did not contribute to improved performance in the more practical task of identifying the location extents of a single village.

Finally, the independent assessment of the map extracts had indicated that the grouping concepts were rated as the most relevant consideration in less than a third of the locations presented in the Grouped Village category. It was possible, therefore, that both groups had relied on associated physical features rather than the grouping concepts for the majority of their comparison tasks in this category which again would have resulted in the low accuracy scores in matching *probe* to *target* locations.

Conclusion The grouping concepts for pairs or groups of villages had been determined largely by geographical, sociological or historical factors. The Expert group did not appear to use these considerations in their location comparison tasks. The most likely explanations were that they misinterpreted the term location to refer only to the village confines or the task requirements were not contingent upon the domain knowledge possessed by the expert group. Consequently there was no evidence that the Experts integrated the grouping features into their cognitive schemas.

6.6 Summary of Findings

The experimental hypothesis had been that the Expert group would recognise the abstract roles of depicted map features and integrate them into their cognitive schemas according to the functional roles they fulfilled. The experiment successfully demonstrated that the hypothesis was correct for Physical Features but not for Remote Features or Grouping concepts.

The first research question enquired whether Experts would integrate geographic features into their cognitive schemas and had been addressed in Experiment 3a of this thesis. It was researched again here within an altered experimental design. The earlier experiment had required the participants to provide verbal protocols and had set an arbitrary 15 seconds inspection time on all *probe* slides. These requirements had been removed for this study to improve the external validity of the experiment. The accuracy scores for correct matching of *probe* to *target* locations indicated that the Expert group had recognised and integrated the abstract roles of geographical and physical features into their cognitive schemas for the location comparison task. The eye-gaze data confirmed that Experts had higher levels of visual attention on physical or man-made boundaries than the Novices despite recording fewer fixations and shorter study times outside the immediate vicinity of the built up areas. These findings together provided evidence of the Experts' use of cognitive schemas in which physical features were integrated according to their abstract roles.

The study times for the *probe* and composite slides surprisingly did not vary across the groups. The use of schemas by the Experts should have provided improved information processing which might have resulted in shorter study times. Since the increased age of the expert group had not interacted with study times the most likely explanation for the absence of any task time advantages was that Experts had again adopted a more conscientious review of the map extracts as evidenced in the earlier experiment.

The second research question had asked if the Experts had integrated the abstract roles of remote features into their cognitive schemas of the extents of location boundaries. Accuracy scores for correct selection of the *target* slides showed no group differences and a success rate of just above 40% for the Experts and 46% for the Novices. The eye-gaze data revealed that participants from both groups had processed the remote features but had not employed them in the location comparison task. These results failed to confirm that Experts integrated the abstract roles of remote features into their cognitive schemas during map study.

The third research question had examined the possibility that Experts had integrated the abstract roles of grouping concepts into their cognitive schemas. The Experts matched the *probe* slide with the correct *target* slide for less than a third of the locations forming pairs or groups of villages and did not differ significantly from the Novice group. There was evidence that the grouping features had been observed by participants from both groups for at least some of the slides but the accuracy results suggested that the grouping concepts had not been integrated into the Experts' cognitive schemas.

Across all the slides, the Experts' study times had not differed significantly from the Novices although in studying the *probe* slides the Experts consistently focused more of their attention within the immediate urban confines than the Novices.

6.7 Overall Conclusions

The conclusions based on the three research questions are provided below.

Research Question 1: *Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping geographic features according to abstract roles?*

- Experts accurately judged location boundary similarities by the functional aspects of geographical or physical features for more than half of their comparison tasks and significantly more frequently than the Novices.

- Experts studied the roles of geographical and physical features more frequently than the Novices as demonstrated by their eye-gaze data.

- The Experts identified the roles of the physical features in relation to the surrounding landscape with fewer fixations than the novices suggesting these features constituted elements of their prototypical configurations.

- The Expert group appeared to employ specialist schemas in which physical features were encoded and retrieved according to their functional and abstract roles.

Research Question 2: *Do expert map readers integrate the abstract roles of remote but associated features within their schemas of what constitutes the outer extent of a locality?*

- Participants from both groups judged *target* locations with similar remote features to the *probe* as having similar boundary extents for less than half of the 12 probe locations.

- The eye-gaze data confirmed that the remote features were being processed by participants from both groups. However the remote features did not appear to contribute to consistent selections of the *target* location in the comparison task.

- All Participants had made some *target* selections based on remote features but the Expert group's performance had not differed significantly from the Novice group.

- The results did not confirm that the Experts had processed the abstract roles of the remote features within their cognitive schemas.

Research Question 3: *Do expert map readers integrate the abstract roles of conceptual grouping features into their schemas of what constitutes the extent of the community boundaries?*

- Participants from both groups judged *target* locations with similar grouping features to the *probe* as having similar boundary extents for less than thirty percent of the seven probe locations.

- The grouping features were processed by participants from both groups as confirmed by the eye-gaze data but did not appear to influence participants' selections of the *target* location in the comparison task.

- Participants did not appear to judge that the grouping features might constitute conceptual boundary extents in the location comparison task.

- The results did not confirm that Experts integrate the abstract roles of grouping concepts within their cognitive schemas

Chapter 7 Closing Summary and Discussion

In this chapter the aims of the thesis are revisited. The findings with respect to those aims are summarised and discussed and the implications for future research are examined.

7.1 Revisiting the Research Aims

The aim of the thesis was to investigate the nature of expertise in topographic map usage.

The literature reviewed in Chapter 2 revealed that the acquisition of expertise in any domain is a complex and protracted procedure in which efficient cognitive processing of domain-relevant information is only one of a number of pre-requisites for expert performance. Deliberate practice, domain knowledge, task familiarity and adoption of relevant decision strategies also contribute to competency for a specific task.

However, the research conducted within this thesis focused specifically on the information-processing strategies employed by Skilled and Expert map users during the encoding and recall of map features. Where earlier studies have provided evidence that experienced map users may have employed information chunking or cognitive templates to assist in the encoding of geographic features during map usage, none of these studies identified which features were grouped into chunks or the criteria employed to categorise them. Knowledge of how experts process geographic features is relevant when attempting to identify the nature of expert map readers' superior skills for interpreting map data rapidly and efficiently. Similarly, an understanding of how experts consider and classify geographic features during map study has important implications for cartographers and GIS designers interested in representing data with related functionality in bespoke applications.

Use of feature configurations sharing either spatial similarities or functional equivalence in Experiment 3a provided opportunities to analyse how experts processed map data during encoding. The use of features adjacent to locations but sharing properties which might determine boundary extents in Experiment 3b satisfied an additional research aim to examine which features are consistently included in traditional concepts of what constitutes the extent of a village location.

Features selected for Experiment 3b were identified therefore both for the functional relevance that experts might attribute to them when grouping features within their cognitive schemas and for their assessed contribution in defining the outer boundaries of village locations.

Experimental designs were reviewed and adapted in order to satisfy these research aims within the three separate experiments.

7.1.1 The research questions

The primary research question for this thesis was: What is the nature of the information processing strategies employed by experts in map reading and comprehension?

The research in each of the three experiments addressed the main research question within a set of questions relating to the nature of cognitive processing being examined.

7.1.2 Experiment 1

The first experiment had been adapted from an earlier study by Gilhooly et al. (1988) and investigated Skilled and Novice map readers in a task of studying and recalling firstly a town map and secondly a contour map. The hypothesis had been that the experienced group would have specialist knowledge for the topographical data in the contour map but would have no advantage over the Novices in the more rudimentary town map task. The first two questions to be researched were therefore:

1. *Do experienced map readers have better recall for map information than less experienced map users?*
2. *Do skilled contour map readers have a superior memory advantage for both contour and non-contour information?*

As predicted the two groups did not differ in their recall performance in the town map task. In the contour map task however the Skilled group recalled more contour related data on their maps than the Novices. The Skilled map readers, therefore, demonstrated that for a non-contour map they had no advantage in recall performance over the less experienced group but when the task demands included their specialist knowledge of contours, the Skilled group had better recall for contour-related but not for general geographical features.

The third research question examined how the participants had processed the map features and asked:

> 3 *Do experienced map readers employ cognitive strategies such as information chunking during encoding and recall of map information?*

It had been anticipated that the Skilled map readers' familiarity with contour related features would facilitate the chunking of the geographic data and this would be evidenced in fewer long (inter-chunk) pauses among the Skilled group. Although the experienced participants processed more contour related data than the Novices within the same study times the trace data did not identify any clear group differences in pause patterns between the groups. This may have been due to the task complexity and heterogeneity of copying strategies which masked any clear patterns and prevented meaningful comparisons between the Skilled and Novice groups. It had not, therefore, been possible to verify that the experienced group had used information chunking from the trace data alone. However, evidence from the trace data and verbal protocols revealed differences in how the groups had processed the contour data and provided answers to the fourth research question:

> 4 *Do experienced map readers employ cognitive strategies such as templates to assist in the processing of spatial information presented on a map?*

Examination of the move-distance data recorded on the tracing tablet indicated that the Skilled group had encoded features that were more widely distributed on the map presentation. The experienced group also made more references to relational encoding, height inference and specialist schemas in their verbal protocols than the Novices. The two results provided converging evidence that the Skilled group had encoded features within prototypical configurations according to semantic, topographic or spatial correspondence and not merely by their close proximity to adjacent features. The findings were consistent with the use of cognitive schemas or templates for the processing of domain-specific topographic information by the Skilled map users.

7.1.2 Experiment 2

Although the first experiment had successfully replicated the Gilhooly et al. (1988) study, two weaknesses in the research design were subsequently identified. The two map tasks had not been counterbalanced and not all the Novice participants were native English speakers. Lack of counterbalancing might have introduced practice effects which could have benefited the Skilled group disproportionately and the cognitive demands of providing a verbal protocol in English may have disadvantaged the Novices for whom English was not their first language. A second experiment was therefore conducted which repeated the research conducted in Experiment 1 within a modified experimental design to address these two issues.

As before, the two groups did not differ in their recall for town map data and once again the Skilled group recalled more contour data on their map sketches. The Skilled group also provided more accurate answers than Novices for the modified contour map questions. The results reaffirmed that the superior performance of the Skilled participants in sketching the contour map was directly attributable to their greater familiarity with contour data and again demonstrated the task-specific nature of their expertise.

No within-group differences were evident for task-order effects when the counterbalanced map results were compared.

As in Experiment 1, no group differences were obtained for pause durations above one second during the compilation of contour map sketches. However, consistent with the earlier results, the Skilled group were again found to make entries on their sketches at greater distances apart than the Novices. Evidence that the Skilled group were interpreting contour features within complex contour configurations and integrating features with the topographic data significantly more often than the Novices was again observed in the verbal protocols. Taken together, these results supported the hypothesis that Skilled map readers were processing features as information chunks and may have been identifying contour features within familiar contour configurations by the use of cognitive schemas such as templates.

The results validated the findings reported in Experiment 1 and duplicated the earlier evidence to address the first four research questions of this thesis.

7.1.3 Experiment 3a

In the third experiment, 20 field surveyors formed the Expert group to complete location comparison tasks. Each *probe* location had boundaries that were similarly matched by spatial configuration in the *distractor* slide and by physical features performing corresponding boundary functions in the *target* slide. Participants were monitored using recordings of their verbal protocols and eye-gaze data. The first research question in this experiment sought confirmation that the Experts were employing specialist information processing strategies for the experimental task and asked:

1. *Do expert map readers employ cognitive schemas such as templates when engaged in a map comprehension task?*

From the verbal protocols it was observed that the Expert group made significantly more use of 'geographical boundaries' and the integration of those features into known configurations to visualise the extent of the boundaries for each location. The Expert group also described locations within prototypical configurations in their 'specialist schemas' significantly more often than the Novices. From the eye-gaze data the Experts were observed to have focused more of their attention within the urban confines of each location than the Novices. Yet the Experts processed more of the relevant geographical features outside the urban area with fewer visual inspections overall. The Experts also studied significantly fewer independent and unrelated features than the Novices. The observed search and study patterns were entirely consistent with the efficient use of schema driven processing of familiar feature configurations by the Experts.

The second research question examined if the participants had employed pattern recognition procedures in their choices of location similarity:

2. *Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping features according to familiar patterns?*

To test for this assumption, the *distractor* location had provided features with high geometric congruence to those in the *probe* slide, albeit generally at a different orientation. As anticipated, the results showed that the *distractor* was chosen as the location with boundaries most similar to those in the *probe* slide by the Novice group. This accounted for more than half their choices. Pattern recognition had, therefore, been the overriding consideration for the Novices for the comparison task. The Experts had significantly fewer instances of choosing the *distractor* slide but were nevertheless shown to have chosen it for 45% of their location comparisons. Therefore, features had been grouped according to the visual patterns they presented on the map for some of the comparison tasks by participants from both groups.

The third research question fulfilled a key aim as it investigated whether the experts would identify the functional roles of geographic features in forming location boundaries. It was:

3. *Does the implicit specialist knowledge held in their cognitive schemas assist expert map readers in identifying and grouping features according to abstract roles?*

Participants had been required to identify the function of the features in determining the boundaries in the *probe* slide and then to search for features performing similar roles in the *target* (or *distractor*) slide. The experimental task had been designed to be demanding in order to test the specialist knowledge of the Experts.

Despite the difficulty of the task, the results, nevertheless, indicated that the Experts had used the abstract roles of features as their criteria for selecting the *target* locations for 55% of their choices. This was significantly higher than the number of correct selections made by the non-experts. Both the eye-gaze data and the verbal protocols confirmed that the geographic features fulfilling abstract roles as boundaries were attended to significantly more often by the Expert group. This suggested that the Experts had indeed identified the functional roles of features and had processed these features in their schemas according to their functional and abstract roles.

Interestingly, the Experts had not completed their comparison tasks quicker than the Novice group despite the clear evidence that they were employing cognitive schemas.

The most likely reason for this counter-intuitive result was the higher level of commitment to the task in the Expert group which may have included more comprehensive validations of their choices by the Experts.

7.1.3 Experiment 3b

Utilising the same participants and similar experimental procedures to those employed for Experiment 3a, the second part of the experiment extended the comparison of the abstract roles of features to include remote but related village features and grouping concepts. Where the earlier experiment had verified that Experts identified and encoded physical features according to the functional boundary roles they fulfil, this study investigated the roles of remote features in extending the perceived village boundary and the concept that grouped villages may possess a communal boundary. A total of 34 locations containing physical boundaries, remote features or grouping concepts were divided between two separate tests and counterbalanced across participants. Eye-gaze data had again been recorded but participants' verbal protocols had not been requested for this experiment.

The first research question in this study again set out to confirm that Experts were employing specialist knowledge for the experimental task.

1. *Does the implicit specialist knowledge held in cognitive schemas assist expert map readers in identifying and grouping geographic features according to abstract roles?*

For the 12 locations in which the boundaries were determined by physical geographic features the Experts again selected almost 60% of the correct *target* slides. This result was significantly higher than the Novice group. The Expert group had again identified and incorporated the functional aspects of physical features in their assessments of boundary extents. The eye-gaze data confirmed significantly more efficient processing of geographic features by the Expert group and suggested that geographical features had been grouped in their cognitive schemas by virtue of the abstract roles they were performing.

This result was not replicated for the second research question which asked:

2. *Do expert map readers integrate the abstract roles of remote but associated features within their schemas of what constitutes the outer extent of a locality?*

Of the 13 locations with remote features the Experts matched fewer than half (42%) correctly with the *target* location and their performance did not differ from the Novice group. Eye-gaze data confirmed that participants from both groups had processed the remote features but had not appeared to integrate them into their schemas for the boundary comparison tasks.

A similar pattern was observed for the grouping features for which the research question had been:

3. *Do expert map readers integrate the abstract roles of conceptual grouping features into their schemas of what constitutes the extent of the community boundaries?*

Seven of the *probe* locations had presented grouping features but less than a quarter of the Experts' comparisons matched the *probe* with the *target* locations having similar grouping concepts. This result closely matched the Novice scores and resulted in no significant group differences. There was some evidence that participants had attended to the paired villages on two of the target slides but there was no confirmation that either the Experts or the Novices had processed the grouping concepts within their schemas for the boundary identification task.

In Experiment 3b the Experts had, therefore, successfully replicated their results for the physical feature boundaries as observed in the previous study but when the remote and grouping concepts were being considered, both groups of participants had not identified their relevance. Three possible accounts to explain these findings were considered. Firstly, the Experts may have misinterpreted the task and restricted their assessments of location boundary to the urban extents of the village alone. Secondly, their specialist knowledge of location boundaries may not have included the two additional attributes of remote features or grouped village categories for location comparison. So the Experts may have been operating outside their domain-specific expertise and consequently had no advantage over the Novice group. A significant interaction was evident in a comparison between the type of task and the Expert group's performance and this lent some support to the latter explanation. Thirdly, a post hoc analysis of the map materials by two independent assessors had shown that when remote and grouping features were prioritised in the order of their importance to other boundary features all remote features and grouping elements were included in the first three choices. However, the remote features were only selected as first choice for approximately 40% of the assessors' selections and the grouping features for only twenty-eight per cent. Since these figures closely correlated with the original scores for selection of correct target slides by the two experimental groups it was possible that the remote and grouping features were considered relevant for all of the locations but only when they were judged to be the most salient factor in defining the boundary extent were these concepts incorporated into the location comparison task.

7.2Summary of findings

Across all three experiments, the Skilled and Expert map users employed cognitive strategies in which map features were integrated into prototypical configurations. As a result the Skilled participants demonstrated a more comprehensive understanding of the topography studied in Experiment 1 and 2, while the Experts made more accurate judgments of the functions of features in performing the roles of boundaries in Experiments 3a and 3b.

In the first two experiments, the earlier finding of Gilhooly et al. (1988) that skilled performance at contour map reading was not a reliable predictor for superior performance for all types of maps was replicated. This result highlighted the domain-specific qualities of expertise described earlier (Shanteau 1992). Although the analysis of trace data had not specifically identified the information chunking described in the Chase & Simon (1973a; 1973b) literature, the cognitive strategies employed by the Skilled participants had closely matched the descriptions of information processing strategies suggested by Template theory (Gobet, 2005; de Groot & Gobet, 1996; Gobet & Charness, 2006) in the chess literature and in the earlier studies of map expertise (Chang et al., 1985; Gilhooly et al., 1988; Thorndyke & Stasz, 1980). The design adopted for the first two experiments had however improved on the Gilhooly design by producing a more comprehensive set of verbal protocols from both groups of participants and in providing a more detailed analysis of sketch activity by the introduction of the tracing tablet.

Experiment 3a produced an original finding. The Experts integrated physical features into their cognitive schemas according to their abstract functional roles for just over half their location choices. For the remainder of their selections the Experts adopted the pattern recognition procedures favoured by the non-experts. These findings supported both the Template theory account which suggests features are processed according to familiar spatial configurations (Gobet, 1997) and the more recent proposition of Linhares & Brum (2007) that features, at least in a chess domain, may be processed according to their abstract roles. None of the earlier studies had examined the cognitive strategies employed by expert map readers at this level of detail.

In Experiment 3b, the Experts failed to integrate remote or grouping features into their cognitive schemas according to their possible roles in extending village boundaries. These findings were not in accord with the study by Davies (2009) where neighbourhood names had been powerful predictors for defining that a location was part of a larger community. Feature functionality had also been addressed by Barsalou (1985). A remote feature could be considered as performing a function integral to the perceived function of the community. In such an instance the feature might contribute to the overall construct of Barsalou's prototypical ideal for a goal-derived category and would be judged as an essential element of the overall location. The Expert group did not appear to have reached this conclusion for the majority of the remote features. This may have been due to an experimental effect induced by the task description or a lack of relevant expertise for assessing how remote features might contribute to conceptual boundaries. It may also have reflected the degree of individual variation in judgement of neighbourhood extents depending on the perspective adopted as observed in the Davies (2009) study. However, this experiment had again examined the type of processing conducted by the participants at the finely focused level of individual features, in addition to providing useful insights into which physical components the experts included when defining location boundaries.

7.3 Implications for conventional cartographic research

The finding that the Expert group had processed some geographic features according to their functionality was in line with much of the literature on expertise in other domains. The electronics engineers tested by Egan & Schwartz (1979) and the software designers of Sonnentag (1998) referred to in the literature review had demonstrated better comprehension of the experimental tasks through a deeper understanding of the principles involved. With the evolvement of their expertise, experienced map readers would be expected to develop a comprehensive knowledge-base of feature functionality within the landscapes they surveyed and to employ this knowledge either implicitly or explicitly when engaged in related map-reading activities. The important finding that is relevant here, however, is that features having similar functions, or perhaps related by a common purpose, may well have been processed by the Experts within a prototypical configuration acquired through the gradual appreciation of the functional properties of all the relevant structures.

In the participants' verbal protocols in all three Experiments there was evidence that members of the Skilled and Expert groups were not merely reading the height data provided by the contour lines. More precisely, they were interpreting what was being represented by the information. The village of Dundon was located between two hills which by their steepness acted as boundaries. Experts and Novices alike made that observation. What the Experts alone noted, however, was that Dundon had evolved between the hills because the area was higher than the flood plain to the South. The height of the water table in any area is not specified on an Ordnance Survey map but as demonstrated by the Experts may be estimated by studying the relationships of displayed features. The question arises, therefore, should this information be more accessible to the less skilled map users through the introduction of an additional convention for possible flood levels such as those depicted on marine charts?

This is probably not practical. The amount of information that a map can support is determined by a large number of factors including the level of detail required, the clarity and legibility of the presentation and the user needs. Ordnance Survey Landranger and Explorer series maps are employed for a wide variety of uses. To cater for such a diversity of needs, a largely generic presentation has been adopted in which major physical features are displayed and by the use of conventional symbols more specific detail related to established user needs are included. While the OS Road Map series provides one example of a map designed to meet the needs of one particular type of user, the development of task-specific maps has not been pursued by the paper map branch of Ordnance Survey for three primary reasons. Firstly, the paper map sector of OS products represents only 20% of their business (Lilley, 2003). Secondly, the production of paper maps with detailed data of interest to one specific task or discipline is commercially unsound. Thirdly, and most importantly, GIS development has largely superseded this requirement.

Although the findings of this paper may have therefore only partial relevance for traditional paper map production, they nevertheless have particular significance for GIS design and development as discussed in the next section.

7.4 Implications for GIS Development and Design

Geographic Information Systems display spatial information in geo-representations using a range of selected formats. These include conventional maps, aerial photographs, 3D terrain models and diagrammatic representations of underground services. Data bases can be constructed from a number of sources and then revised and adapted by users according to task requirements. Ordnance Survey provides four levels of reference data in their MasterMap™ product incorporating a detailed topography layer comprehensively populated with minute detail of major features such as roads, buildings, natural features and administrative boundaries. A second layer contains address information for all commercial and residential properties. A third layer incorporates detailed aerial imagery while the final layer maps the country's transport infrastructure. Each of these presentations may be selected independently or integrated with customised data bases designed for individual or organisational requirements.

A GIS display thus differs fundamentally from a paper map. The information presented is not restricted by level of detail or presentational limitations. With an ability to select specific data sets or components within the data sets the user has the facility for displaying information for highly specialised tasks in bespoke formats.

Where the paper map presentation is limited by space constraints in the quantity of information which can be included in the presentation, the GIS display has the capability of filtering the majority, if not all of the generic information to provide the user with an uncluttered display containing only the data relevant to the task requirements. The Novice participants in the boundary identification task for the village of Dundon reported in Experiment 3a of this study might have benefited from a display of flood levels. If their presentation had been a GIS application and not a conventional map format this might have been provided as an option. However the Novices would still have required sufficient understanding of the relevance of the water table to the development of settlements in order to include this concept in their decision making.

The effectiveness of a GIS is therefore not determined simply by the quantity or quality of information it can display, but on how the user interacts with that information. These two considerations are central to the study of expertise in GIS research and have been investigated under the separate headings of interpreting spatial information displays and the more practical tasks of employing GIS tools (Davies 2005). The findings of this thesis are however highly relevant to both these areas of GIS research as discussed in the following sections.

7.4.1 Viewing and interpreting GIS displays

The flexibility of display options and the variety of data presentations employed in the GI community reflects the corresponding diversity in user requirements and capabilities. While good design and the incorporation of human-computer interface considerations can contribute to enhancements in data comprehension, there remains a core element of user skill which determines how efficient the GIS may be in providing the required information. Davies (2005) refers to two forms of GI user expertise - macro spatial and micro spatial knowledge. Macro spatial knowledge, the author defines as the understanding of the geographic landscape that is represented in the display, while micro spatial knowledge is an awareness of the information structure of the representation itself. The two types of knowledge are linked by a comprehension of the semiotics of the representation.

For some purposes, such as updating large scale map excerpts from an aerial photograph, the geometric properties of the representation may be more relevant than an appreciation of the real world environment portrayed. For many other usages such as emergency planning, however, perception of the structure of the geographic features represented by the symbols in the display might be an essential requirement for rapid and effective decision making. Davies suggests that where expertise in paper map usage is predominately concerned with the latter of these two processes the nature of GIS expertise may involve a meta-cognitive analysis of task requirements to identify the suitability for adopting either macro spatial or micro spatial knowledge structures.

Findings from this thesis are relevant to both these knowledge bases. It has been shown that Experts process features according to their abstract roles in conventional cartographic tasks. The macro spatial knowledge identified in GIS expertise is also dependent on skilled interpretation of the external environment represented within the display. It follows, therefore, that a better understanding of how expert map readers might group features in their cognitive schemas should contribute to an appreciation of how expertise is acquired for many of the other GIS tasks in which macro spatial knowledge is employed. The importance of the functionality and the abstract roles fulfilled by features will naturally vary across the diverse tasks for which GI displays are used. However, an understanding that both spatial configuration and functional roles are employed in experts' schemas might assist operators to develop expertise in interpreting GI presentations. This knowledge may be widely applicable across a variety of disciplines and for fundamentally different data sets. Indeed, the common thread for developing expertise for each of the selectable display options in a complex GI display might be to process the data according to an acquired understanding of the functional properties of the represented features in addition to an appreciation for their spatial layout. In the micro spatial knowledge structure which also contributes to GIS expertise there is less dependence on the integrated processing of geographic features. For the routine digitising and data updating tasks involving predominately geometric pattern matching it is probable that the represented features are processed primarily according to spatial determinants but semantic and functional properties will not be entirely absent. In these tasks the functional roles of features may, therefore, be processed implicitly rather than explicitly, but there are likely to be at least some applications where individual feature processing through combining pattern matching and knowledge of functional roles contributes to a better comprehension of the data being processed.

7.4.2 Development of bespoke GI presentations and the use of GIS tools

The Information that is presented on GIS displays is determined initially by the design team in response to a perceived user requirement. However this is only the beginning of what may be a constant process of evolvement. Modelling software packages may be coupled to the GIS software with engineered user interfaces to generate environmental models and highly- specialised presentations. Raw data with customised content can be adjusted into a common frame of spatial reference and then scaled and formatted to match the purchased GIS data. The combined data may then be synthesised and aggregated to meet specialised end-user applications.

In many instances this may be achieved by modifying the GIS software without the use of engineered interfaces in a process described as embedded modelling (Stocks & Wise, 2000). So, where paper map production has traditionally been conducted by specialist cartographers with the benefits of wide ranging research, GI Systems may be modified by software engineers who are unlikely to be conversant with the specialist knowledge held within the cartographic community.

Knowledge of how an expert map reader processes spatial data may not have implications for all the design considerations addressed by engineers modifying GIS presentations. However, for some applications the principles governing paper map comprehension will be highly relevant. In these instances the finding that experts employ spatial configurations and feature functionality when processing map presentations might greatly improve GIS design. For instance, a traffic coordinator despatching an ambulance would benefit from a presentation which groups traffic obstacles such as level crossings or busy roundabouts not merely by type but by their similarities in the current expected length of delay. These may be dependent on time of day or seasonal considerations all of which will vary but can be programmed to incorporate feature functionality into the spatial display. Where the operator is also the system modifier there is therefore a further facility for user expertise to be integrated into the GI system and upgraded as additional functional requirements are identified.

It is probable therefore, that GIS development and modification will increasingly be conducted by non-cartographers working within design requirements which at first glance appear to have little relevance to traditional map reading. The knowledge of how spatial information is processed, so comprehensively researched within the cognitive cartographic community, may be in danger of being eclipsed. So, it is important to note that complex GIS presentations may provide opportunities for data presentations far more complex and specialised than those achievable with a paper map, but they are still spatial presentations. As such the principles relating to cognitive processing of spatial data will continue to operate at a fundamental level. Research into expertise in map reading will therefore continue to provide useful insights into the skilful operation of GIS displays.

7.4.3 Further research into 'fuzzy boundaries', 'vernacular geography' and the processing of geographic features in map reading

Finally, the research presented in this thesis investigated the relationship of abstract roles in the processing of geographic features in the cognitive schemas of Expert participants. By instructing the Experts to compare similarities of boundary extents for a variety of locations, the finding was that neither Experts nor Novices consistently included remote features or grouping concepts in their considerations. This finding was counter-intuitive in the light of studies which indicate that local residents do, on many occasions, judge boundary extents by such factors.

Further research which attempts to extend our understanding of the processing of functional roles of features would need to address how the task characteristics might have affected this result. As Barsalou (1985) observed, the concept of an entity is not invariant. Similarly, concept of place as an entity is not invariant and is reliant on perspective. Our surveyors did not appear to assume the perspective of a local inhabitant for the task. Indeed the task instructions had asked them to consider the task from their own perspective.

Davies (2009) had also shown that these same professional surveyors had altered perspectives of what features were relevant in identifying a neighbourhood when considering either their own or a more distant neighbourhood. Thus, although the experimental design had successfully demonstrated how some geographic features were processed it had not fully addressed the complexity of decision making employed in the association of remote features with a location. Future research, therefore, needs to study these decision making processes in isolation and from a number of different perspectives.

While the ideas examined within this research were related to the interpretations of Experts engaged in a paper map-reading task, the findings again have implications for GIS researchers. In displays where a number of presentation options are available, places may be displayed using a diversity of criteria. If information on local transport is a selectable option then the similarity of two locations with a remote rail station would be more immediately obvious and may be more relevant for the task. Here the context of information gathering would identify the grouping features. The strength of GI systems is that they are not limited by the amount of information they may display. Hence, the problems encountered by cartographers when attempting to model place extent by fuzzy concepts and vernacular geography may be addressed by simply introducing a display for each set of criteria. Where research into concept of place was in the past constrained by limitations in how to represent such a diversity of constructs, the flexibility of GIS now provides both a method of representation and the impetus to research fully all the conceptual categories which may be required by the users of bespoke displays.

The findings in Experiments 3a and 3b that the Expert participants processed the geographic features representing the location boundaries with fewer fixation counts and shorter gaze lengths than the Novices corresponded to the earlier findings of Chang et al (1985) where the experienced map readers had processed familiar contour patterns with greater efficiency. In line with research into expert performance in other domains, the acquisition of expert map-reading skills would appear to be dependent on interpreting the processed information rapidly to achieve a full understanding of what is being represented on the map with a minimum number of visual inspections. Computer models of expertise in which problem solving is represented in the cognitive architecture by a number of iterative processes which may be progressively reduced with the acquisition of domain relevant knowledge – eg. ACT-R (Anderson, 1996), highlight the importance of studying firstly how map experts might differ in how they inspect the map but also which cognitive processes appear to be absent or significantly less evident in the map inspections carried out by experts when compared to the novices. Future work into map reading expertise might therefore benefit from an appreciation that knowledge of the functionality of geographic features, as well as familiarity with their often-encountered related spatial configurations, may enhance both the speed and efficiency of the cognitive processing of map data, but the evidence for this may lie in an apparent inattention to features with properties that are commonplace to the expert reader. Such studies would also need to address the requirement to gather participant data from several sources so that anomalies such as reduced visual attention can be shown by a corresponding performance measurement to reliably represent an important component of expertise and not merely an apparent shortcoming in performance.

Bibliography

Ackerman, P. L., & Cianciolo, A. T. (2000). Cognitive, Perceptual Speed and Psychomotor Determinants of Individual Differences During Skill Acquisition. *Journal of Experimental Psychology: Applied, 6*(259-290).

Agarwal, P. (2005). Topological and Geometric Operators for Ontological Classification of Vague Geographic Concepts. *Spatial Cognition and Computation, 5*(1), 69-88.

Anderson, J. R. (1996). ACT: A Simple Theory of Complex Cognition. *American Psychologist, 51,* 355-365.

Artez, A. J. (1991). The Design of Electronic Map Displays. *Human Factors, 33,* 85-101.

Audet, R. H., & Abegg, G. L. (1996). Geographic Information Systems - Implications for Problem-solving. *Journal of Research in Science Teaching, 33*(1), 21-45.

Barkowsky, T., & Freksa, C. (1997). Cognitive Requirements on Making and Interpreting Maps In S. C. Hirtle & A. U. Frank (Eds.), *Spatial Information Theory: A Theoretical Basis for GIS. COSIT1997*. Berlin: Springer.

Barsalou, L. W. (1985). Ideals, Central Tendency and Frequency of Instantation as Determinants of Graded Structure in Categories. *Journal of Experimental Psychology: Learning Memory and Cognition, 11*(4), 629-654.

Bennett, B., & Agarwal, P. (2007). *A Semantic Analysis of Place Terms.* Paper presented at the COSIT 2007, Melbourne, Australia.

Blades, M., & Spencer, C. (1986). How do People use Maps to Navigate through the World? *Cartographica, 23*(4), 64-75.

Bordogna, G., Chiesa, S., & Geneletti, D. (2006). Linguistic Modelling of Imperfect Spatial Information as a Basis for Simplifying Spatial Analysis. *Information Sciences, 176*(4), 366-389.

Castner, H. W. (1983). Research Questions and Cartographic Design. In D. R. F. Taylor (Ed.), *Graphic Communication and Design in Contemporary Cartography* (Vol. 2, pp. 87-113). Chichester: John Wiley.

Caulford, P. G., Lamb, S. B., Kaigas, T. B., Hanna, E., Norman, G. R., & Davis, D. A. (1994). Physician Incompetence: Specific Problems and Predictors. *Academic Medicine, 69*(S16-S18).

Chabris, C. F., & Hearst, E. S. (2003). Visualisation, Pattern Recognition, and Forward Search: Effects of Playing Speed and Sight of the Position on Grandmaster Chess Errors. *Cognitive Science 27*, 637-648.

Chang, K., Antes, J., & Lenzen, T. (1985). The Effect of Experience on Reading Topographic Relief Information: Analysis of Performance and Eye Movements. *The Cartographic Journal, 22*(2), 88-94.

Charness, N. (1976). Memory for Chess Positions: Resistance to Interference. *Journal of Experimental Psychology: Human Learning and Memory, 2*, 641-653.

Charness, N. (1979). Components of Skill in Bridge. *Canadian Journal of Psychology, 33*, 1-50.

Charness, N., Krampe, R. T., & Mayr, U. (1996). The Role of Practice and Coaching in Entrepreneurial Skill Domains: An International Comparison of Life-span Chess Skill Acquisition. In K. A. Ericsson (Ed.), *The Road to Excellence: the Acquisition of Expert Performance in the Arts, Sciences and Sports and Games* (pp. 51-80). Mahwah NJ: Erlbaum.

Charness, N., Tuffiash, M., Krampe, R. T., & Reingold. (2005). The Role of Deliberate Practice in Chess Expertise. *Applied Cognitive Psychology, 19*, 151-165.

Chase, W. G., & Ericsson, K. A. (1982). Skill and Working Memory. In G. H. Bower (Ed.), *The Psychology of Learning and Motivation*. New York: Academic Press.

Chase, W. G., & Simon, H. A. (1973 b). Perception in Chess. *Cognitive Psychology, 4*, 55-81.

Chase, W. G., & Simon, H. A. (1973a). The Mind's Eye in Chess. In W. G. Chase (Ed.), *Visual Information Processing* (pp. 215-281). New York: Academic Press.

Cheng, P. C.-H., & Rojas Anaya, H. (2004). TRACE User Guide. *(Unpublished Representational Systems Laboratory Report)*.

Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). Categorisation and Representation of Physics Problems by Experts and Novices. *Cognitive Science, 5*, 121-152.

Coluccia, E., & Louse, G. (2004). Gender Differences in Spatial Orientation: A Review. *Journal of Environmental Psychology, 24*(3), 329-340.

Cornell, E. H., & Heth, C. D. (2001). Route Learning and Way-finding. In R. Kitchen & S. Freundschuh (Eds.), *Cognitive Mapping: Past Present & Future*. London: Routeledge.

Cornell, E. H., Sorenson, A., & Mio, T. (2003). Human Sense of Direction and Wayfinding. *Annals of the Association of American Geographers, 93*(2), 399-425.

Crampton, J. (1992). A Cognitive Analysis of Wayfinding Expertise. *Cartographica, 29*(3/4), 46-65.

Davies, C. (2002). When is a map not a Map? Task and Language in Spatial Interpretation with Digital Map Displays. *Applied Cognitive Psychology, 16,* 273-285.

Davies, C. (2005). Spatial Expertise and Geographic Information: Towards a Testable Model. Ordnance Survey.

Davies, C. (2009). *Are Places Concepts? Familiarity and Expertise Effects in Neghbourhood Cognition*. Paper presented at the COSIT 2009.

Davies, C., Holt, I., Green, J., Harding, J., & Diamond, L. (2008). *User needs and the Implications for Modelling Place*. Paper presented at the International Workshop on Computational Models for Place (PLACE 08).

Davies, C., & Medyckyj-Scott, D. (1996). GIS Users Observed. *International Journal of Geographic Information Systems, 10*(4), 363-384.

de Groot, A. D. (1965). *Thought and Choice in Chess, 1st edition*. The Hague: Mouton.

de Groot, A. D., & Gobet, F. (1996). *Perception and Memory in Chess: Heuristics of the Professional Eye*. Assen: Van Gorcum.

Downs, R. M. (1985). The Representation of Space: It's Development in Children and in Cartography. In R. Cohen (Ed.), *The Development of Spatial Cognition* (pp. 323-345). Hillsdale, N.J.: Lawrence Erlbaum.

Durso, F., & Dattel, A. R. (Eds.). (2006). *Expertise and Transportation*. New York: Cambridge University Press.

Eastman, J., & Castner, H. (1983). The Meaning of Experience in Task-specific Map Reading. In D. R. F. Taylor (Ed.), *Graphic Communication and Design in ContemporaryCcartography* (pp. 115-148). Chichester: John Wiley.

Eccles, D. W., Walsh, S. E., & Ingledew, D. K. (2006). Visual Attention in Orienteers at Different Levels of Experience. *Journal of Sports Sciences, 24*(1), 77-87.

Egan, D. E., & Schwartz, B. J. (1979). Chunking in Recall of Symbolic Drawings. *Memory & Cognition, 7,* 149158.

Elo, A. E. (1986). *The Rating of Chess Players, Past and Present* New York: Arco Chess.

Ericsson, K. A., & Kintsch, W. (1995). Long Term Working Memory. *Psychological Review, 102*, 211-245.

Ericsson, K. A., Krampe, R. T., & Tesch-Romer, C. (1993). The Role of Deliberate Practice in the Acquisition of Expert Performance. *Psychological Review, 100*(3), 363-406.

Eva, K. G. (2002). The Aging Physician: Changes in Cognitive Processing and their Influence on Medical Practice. *Academic Medicine, 77*, S1-S6.

Field, A. (2000). *Discovering Statistics Using SPSS for Windows*. London: Sage.

Freeman, S. (2006). The Mistake That Cost Roy Meadow His Reputation. *Timesonline* February 17 2006

French, J., Ekstrom, R., & Price, L. (1963). *Kit of Reference Tests for Cognitive Factors*. Princetown NJ: Educational Testing Service.

Freundschuh, S. (1990). Can Young Children Use Maps. *Cartographica, 27*, 54-66.

Garling, T., & Golledge, R. (2001). Cognitive Mapping & Spatial Decision Making. In R. Kitchen & S. Freundschuh (Eds.), *Cognitive Mapping Past Present and Future* (pp. 44-65). London: Routeledge.

Gibson, B. M. (2001). Cognitive Maps not Used by Humans (Homo sapiens) During a Dynamic Navigational Task. *Journal of Comparative Psychology, 115*(4), 397-402.

Gilhooly, K., Wood, M., Kinnear, P., & Green, C. (1988). Skill in Map Reading and Memory for Maps. *Quarterly Journal of Experimental Psychology, Section A - Human Experimental Psychology, 40A*(1), 87-107.

Gilmartin, P. (1986). Maps, Mental Imagery and Gender in the Recall of Geographical Information. *American Cartographer, 13*(4), 335-344.

Gobet, F. (1997). A Pattern-recognition Theory of Search in Expert Problem Solving. *Thinking & Reasoning, 3*(4), 291-313.

Gobet, F. (1998). Expert Memory: A Comparison of Four Theories. *Cognition, 66*(115-152).

Gobet, F. (2005). Chunking Models of Expertise: Implications for Education. *Applied Cognitive Psychology, 19*, 183-204.

Gobet, F., & Charness, N. (2006). Expertise in Chess. In K. A. Ericsson, N. Charness, P. J. Feltovich & R. R. Hoffman (Eds.), *The Cambridge Handbook of Expertise and Expert Performance*. New York: Cambridge University Press.

Gobet, F., & Simon, H. A. (1996). Templates in Chess Memory: A Mechanism for Remembering Several Boards. *Cognitive Psychology, 31,* 1-40.

Gunzelmann, G., & Anderson, J. R. (2006). Location Matters: Why Target Location Impacts Performance in Orientation Tasks *Memory & Cognition, 34*(1), 41-59.

Gunzelmann, G., Anderson, J. R., & Douglass, S. (2004). Orientation Tasks with Multiple Views of Space: Strategies and Performance. *Spatial Cognition and Computation, 4*(3), 209-256.

Hampton, J. A. (2007). Typicality, Graded Membership and Vagueness. *Cognitive Science, 31*(3), 355-384.

Harley, J. B., & Woodward, D. (1987). *The History of Cartography*. Chicago: University of Chicago Press.

Hartley, T., Bird, C. M., Chan, D., Cipolotti, L., Hasain, M., Varga-Khadem, F., et al. (2007). The Hippocampus is Required for Short Term Memory in Humans. *Hippocampus, 17,* 34-38.

Hoffman, R. R., Shadbolt, N. R., Burton, A. M., & Klein, G. (1995). Eliciting Knowledge from Experts: A Methodological Analysis. *Organizational Behaviour and Human Decision Processes, 62,* 129-158.

Howell, D. C. (1997). *Statistical Methods for Psychology*. Belmont Ca: Wadsworth Publishing Co.

Kahneman, D. (1991). Judgement and Decision Making: A Personal View. *Psycholgical Science, 2*(3), 142-145.

Kent, R. S. G., & Cheng, P. C.-H. (2008). Expertise in a Map Reading Task: The Role of Schemas in the Processing of Topographical Relief Information. In B.C.Love, K.McRae & V.M.Sloutsky (Eds.), *Proceedings of the 30th Annual Conference of the Cognitive Science Society* (pp. 2298-2303). Austin, TX: Cognitive Science Society.

Klippel, A., Tappe, H., & Habel, C. (2003). Pictorial Representations of Routes: Chunking Route Segments During Comprehension. In C. Freksa, W. Brauer, C. Habel & K. Wender (Eds.), *Spatial Cognition III, Routes and Navigation, Human Memory and Learning* (pp. 11-33). Berlin: Springer.

Krahe, B., Temken, J., & Bienbeck, S. (2007). Schema Driven Information Processing in Judgements about Rape. *Applied Cognitive Psychology, 21,* 601-619.

Lawton, C. A. (2001). Gender and Regional Differences in Spatial Referents Used in Direction Giving. *Sex Roles, 44*(5-6), 321-337.

Lee, P. U., & Tversky, B. (2005). Interplay Between Visual and Spatial: The Effects of Landmark Descriptions on Comprehension of Route/survey Descriptions. *Spatial Cognition and Computation, 5*(2 & 3), 163-185.

Levine, M. (1982). You are Here Maps: Psychological Considerations. *Environment & Behaviour, 14,* 221-237.

Liben, L. S., & Downs, R. M. (1989). Understanding Maps as Symbols: the Development of Map Concepts in Children. In H. W. Reese (Ed.), *Advances in Child Development and Behaviour, Vol. 22* (pp. 145-201). New York: Academic Press.

Liben, L. S., & Downs, R. M. (1994). Fostering Geographic Literacy from Early Childhood: the Contributions of Interdisciplinary Research. *Journal of Applied Developmental Psychology, 15,* 549-569.

Liben, L. S., & Downs, R. M. (2003). Investigating and Facilitating Children's Graphic, Geographic and Spatial Development. *Journal of Applied Developmental Psychology, 24,* 663-679.

Linhares, A. (2005). An Active Symbols Theory of Chess Intuition. *Minds & Machines, 15,* 131-181.

Linhares, A., & Brum, P. (2007). Understanding our Understanding of Strategic Scenarios: What Role do Chunks Play. *Cognitive Science, 31,* 989-1007.

Lobben, A. K. (2004). Tasks, Strategies, and Cognitive Processes Associated with Navigational Map Reading: A Review Perspective. *Professional Geographer, 56*(2), 270-281.

MacEacheren, A. M. (1995). *How Maps Work: Representation, Visualisation and Design*. New York: Guildford Press.

Marchant, G., Robinson, J., & Anderson, U. (1991). Analogical Transfer and Expertise in Legal Reasoning. *Organizational Behaviour and Human Decision Processes, 48,* 272-290.

McGuinness, C. (1994). Expert/novice Use of Visualization Tools. In A. M. MacEachren & D. R. F. Taylor (Eds.), *Visualization in Modern Cartography* (pp. 185-199). Oxford: Pergamon - Elsevier Science Ltd.

Meyers, J. E., & Meyers, K. R. (1995). *Rey Complex Figure Test and Recognition Trial*. Lutz Fl: Psychological Assessment Resources.

Monmonier, M. (1996). *How to Lie with Maps* (Second ed.). Chicago & London: University of Chicago Press.

Montello, D. R. (2002). Cognitive Map Design Research in the Twentieth Century: Theoretical and Empirical Approaches. *Cartography and Geographic Information Science, 29,* 283-304

Montello, D. R., & Freundschuh, S. (2005). Cognition of Geographic Information. In R. B. McMaster & E. L. Usery (Eds.), *A Research Agenda for Geographic Information Science* (pp. 61-91). Boca Raton, FL: CRC Press.

Montello, D. R., Lovelace , K. L., Golledge, R., & Self, C. M. (1999). Sex -Related Differences and Similarities in Geographic and Environmental Spatial Abilities. *Annals of the Association of American Geographers, 89*(3), 513-534.

Newell, A., & Simon, H. A. (Eds.). (1972). *Human Problem Solving*. Englewood Cliffs NJ: Prentice -Hall.

Olson, J. (1979). Cognitive Cartographic Experimentation. *Canadian Cartographer, 16*(1), 34-44.

Paivio, A. (Ed.). (1971). *Imagery and Verbal Processes*. New York: Holt Reinhart &Winston.

Postigo, Y., & Pozo, J. I. (1998). The Learning of a Geographical Map by Experts and Novices. *Educational Psychology, 18*(1), 65-80.

Rosenbaum, R. S., Ziegler, M., Winocur, G., Grady, C. L., & Moscovitch, M. (2004). I Have Often Walked Down This Street Before: fMRI Studies on the Hippocampus and Other Structures During Mental Navigation of an Old Environment. *Hippocampus, 14,* 826-835.

Shanteau, J. (1992). Competence in Experts: The Role of Task Characteristics. *Organizational Behaviour and Human Decision Processes, 53,* 252-266.

Slocom, T. A., & Egbert, S. L. (1993). Knowledge Aquisition from Choropleth Maps. *Cartography and Geographic Information Systems, 20,* 83-95.

Sonnentag, S. (1998). Expertise in Professional Software Design: A Process Study. *Journal of Applied Psychology, 83*(5), 703-715.

Stocks, C. E., & Wise, S. (2000). The Role of GIS in Environmental Modelling *Geographical & Environmental Modelling, 4*(2), 219-235.

Talen, E., & Shah, S. (2007). Neighbourhood Evaluation using GIS: An Exploratory Study. *Environment & Behaviour, 39,* 583-615.

Taylor, H. A., & Tversky, B. (1992). Spatial Mental Models Derived from Survey and Route Descriptions. *Journal of memory and Language, 31,* 261-292.

Thorndyke, P., & Hayes-Roth, B. (1982). Differences in Spatial Knowledge Acquired from Maps and Navigation. *Cognitive Psychology, 14,* 560-589.

Thorndyke, P., & Stasz, C. (1980). Individual Differences in Procedures for Knowledge Acquisition from Maps. *Cognitive Psychology, 12,* 137-175.

Tversky, B. (2000). Some Ways that Maps and Diagrams Communicate. In C. Freska, W. Brauer, C. Habel & K. F. Wender (Eds.), *Spatial Cognition II: Integrating abstract theories, empirical studies, formal methods and practical applications* (pp. 72-79). New York: Springer.

Wallace, J. R., & Almy, T. L. (1999). Do Children's Maps Differ for Younger and Older Friends? *Journal of Genetic Psychology, 160*(1), 89-98.

Wood, M. (1992). *The Power of Maps*. New York & London: Guildford Press.

Wood, M. (1993). Interacting with Maps. In D. Medyckyj-Scott & H. M. Hearnshaw (Eds.), *Human Factors in Geographic Information Systems*. London: Bellhaven Press.

Wood, M. (2003). Some Personal Reflections on Change: The Past and Future of Cartography. *The Cartographic Journal, 40*(2), 111-115.

Appendices

Appendix 1 Published Paper - Expertise in a Map Reading Task: The Role of Schemas in the Processing of Topographic Relief Information (Kent& Cheng, 2008).

Appendix 2 Participant Consent form - Experiment 1 & 2

Appendix 3 Familiarity with maps questionnaire - Experiment 1 & 2

Appendix 4.1 Paper Folding Test Instructions

Appendix 4.2 Paper Folding Test

Appendix 5 Town Map

Appendix 6 Town Map Questions

Appendix 7 Contour Map

Appendix 8 Contour Map Questions- Experiment 1

Appendix 9 Participant Consent Form - Experiment 3a & 3b

Appendix 10.1 Map Experience questionnaire Experiment 3a & 3b

Appendix 10.2 Map Experience Questionnaire Experiment 3a & 3b

Appendix 1 Published Paper

Expertise in a Map Reading Task: The Role of Schemas in the Processing of Topographic Relief Information- (Kent, R.S.G. & Cheng, P.C-H, 2008).

In *Proceedings of the 30thAnnual Conference of the Cognitive Science Society* (pp 2298-2303). Austin, Tx: Cognitive Science Society

Expertise in a Map Reading Task: The Role of Schemas in the processing of Topographical Relief information

Robin S.G. Kent (R.S.G.Kent@Sussex.ac.uk)
Peter C-H. Cheng (P.C-H.Cheng@sussex.ac.uk)
Representation and Cognition Research Group
Department of Informatics, University of Sussex
Brighton, BN1 9QH, UK

Abstract

Earlier studies have suggested that proficient map readers employ cognitive strategies such as information chunking and schemas to aid information processing. In this paper experienced and non-experienced map readers studied and reproduced firstly a town map and then a topographical map. No group differences were observed for the town map task. When the topographical map was recalled the experts had better recall for contour related data. They also combined contour related data with individual features more often than less experienced map users and employed specialist procedures during encoding and recall. These findings are consistent with Template theory and schema based accounts of information processing.

Keywords: Expertise; Map-reading; Information chunking; Schemas; Protocol analysis.

Introduction

Expertise and information processing The nature of expertise has been studied within a number of domains. Early work by Chase and Simon (1973) identified superior task-relevant memory skills in chess Masters and attributed this ability to a process of information 'chunking'. Similar studies have shown that experts perform better than novices when engaged in problem solving tasks incorporating electronic diagrams (Egan & Schwartz, 1979), basic electricity circuit diagrams (Cheng, 1999), medical diagnosis (Groen & Patel, 1988) and schematic engineering diagrams (Moss, Kotovsky, & Cagan, 2006). In such comparisons participants reportedly employ cognitive strategies in which information is processed in perceptual chunks. Within each chunk the information contained is consistently greater for experts than for novices.

Experts also appear to employ highly organised memory structures such as schemas (Gobet, 1998), templates (Gobet & Charness, 2006; Gobet & Simon, 1996) and retrieval strategies (Ericsson & Kintsch, 1995). By the employment of such schemas, information processing during encoding into short term memory and retrieval from long term memory is facilitated by the early identification of commonly occurring prototypical configurations and patterns within their domain knowledge. Each of these patterns and configurations may then be processed as single units of information although they may represent a number of individual components.

Expertise in map reading and comprehension is highly dependent on the efficient processing of visually presented information. In addition, the wide variety of tasks associated with topographic (terrain) map usage often require a number of associated skills including, efficient spatial memory performance, an ability to mentally rotate internal and external representations and a familiarity with task-specific map presentations to facilitate the generation of 3D mental representations from 2D displays. At a fundamental level, however, it is probable that for experts the visual information studied on a map is processed both more efficiently and at a deeper level of comprehension than for novices. Since capacity for spatial information in short term memory is limited it is again highly probable that experts employ some form of information chunking and associated cognitive schemas to facilitate rapid and efficient information processing.

Information chunking strategies and map reading Three studies have directly addressed the employment of 'information chunking' strategies in map reading tasks. In the first of these Thorndyke & Stasz (1980) examined individual differences between experts and novices when studying a map in a recall task. Experts were observed to employ two distinct attentional procedures - partitioning (restricting study areas to sub-sets of map information) and dedicated sampling methods. The sampling methods were further sub-divided into four categories – a) Systematic sampling (directed by subject defined rules or criterion); b) Stochastic sampling (shifting to an adjacent area but with no systematic control; c) Random sampling and; d) Memory directed sampling (guided by the last inspection of the map). Experts were further distinguished from novices by their adoption of different encoding strategies such as relational encoding (linking features by their spatial relationship) and labelling (to generate a verbal cue to assist recall). The results from this study suggested that familiarity with maps was not of itself predictive of good performance for the task of memorising and reproducing information from maps. Instead, the employment of good learning strategies for the processing of spatial information and a good visual memory were more reliable predictors of accurate recall of map detail.

Gilhooly et al (1988) addressed the inconclusive results reported by Thorndyke & Stasz and suggested that map reading expertise had not been demonstrated by all the experts in their study because planimetric (non-contour) maps had been used. By including both planimetric and contour maps into their experimental design, Gilhooly et al demonstrated that experts' memory for map detail in the contour maps was superior to that of the novices. However this advantage was not observed for information recalled from the non-contour maps. The authors further reported that the two groups of experts and novices did not differ significantly in the methods they employed to study the maps nor in their use of non-specialist schemata. During recall however, the experts employed more specialist schemas and paused less often than novices. Experts also recalled more of the non-specialist schema information than the less experienced group despite the equal use of 'lay' schemas by both groups during encoding. These results supported the authors' contention that expert map-readers employ a 'rich repertoire of schemata' (p107) to encode information from a map. Since the experts paused less often than novices during map study (measured by recording pauses longer than one second from the videotape record) it was suggested that this might have reflected processing of larger information packages during both encoding and retrieval. This pattern was consistent with the 'information chunking' mechanisms employed by experts in the studies of expertise already cited.

In the third study of map-reading and expertise, Chang, Lenzen & Antes (1985) examined the eye movements of participants engaged in a map reading exercise and found that although both groups did not differ significantly in the number of fixations, experienced map users had shorter fixations on contour related features suggesting easier processing during the integration of contour data into the experts evolving schemas. Experts also performed better on their recall of absolute and relative heights. The authors attributed this superior performance to the experienced participants' ability to process larger chunks of information relating to contour information during the limited available study time. Experts, the authors suggested, may have been more adept at transforming a two-dimensional representation in the form of a map into a three-dimensional mental image of the terrain depicted. When confronted with irregular topographical information or random contour lines the experts' visual search times increased as they struggled to make meaningful patterns from atypical representations.

This result mirrored the additional cognitive processing required by chess masters when recalling random piece positioning and unstructured board layouts in the Chase & Simon (1973) literature.

Summary. Chunking theory and its more comprehensive successor, Template theory provide highly credible accounts of how information processing may be facilitated in expert map users by the employment of schemas containing familiar patterns. In a map reading task where the map corresponds to a known landscape, experts might be expected to encode it not just as separate 'chunks', but within an overall template that incorporates the relationships between the groups of objects viewed (Davies, 2005; McGuinness, 1994). Specifically experts may be: 1.Focussing on the distinctive features of a display to establish how it may differ from the norm; 2. Identifying what is familiar and typical and which therefore requires minimal processing; and 3. Performing spatial feature-matching of either the geometric or symbolic information provided on the map with geographic feature-matching in the landscape being represented (Chang et al., 1985).

The present study The experiment reported here employed a similar experimental design to the Gilhooly et al study. However in the earlier study participants were provided with a map, which they viewed for five minutes, before recalling the information in the form of a sketch. In this study, in addition to a videotape and audio record of verbal protocols, a detailed record of pen strokes and pauses between pen strokes was obtained using an electronic drawing tablet during production of the recalled sketch map. Earlier studies of participants engaged in handwriting tasks, e.g. Cheng & Rojas Anaya (2007) have shown using Graphical Protocol Analysis that the length of pause prior to a pen stroke correlated with the amount of processing relating to the planned action. The processing time in turn correlated with the differences between low-level procedural versus conceptual components of a written phrase and provided a method of identifying the boundaries of chunked information. Pauses during the processing of intra-chunk information were shown to be reliably shorter than those observed between individual chunks. Accordingly it was hypothesized that overall the experienced map users would record a higher number of short (intra-chunk) pauses between pen strokes than the novice group since more remembered items would be held in each information chunk. Similarly the experts were anticipated to record fewer long (inter-chunk) pauses than the novices. It was further anticipated that these group differences would be evident only for the more complex task characteristics of interpreting and remembering information from the contour map

Method

Participants: Eight experienced map-readers and eight novice map-readers were recruited from students and staff at the University of Sussex. The experienced group comprised two lecturers with the Informatics department who were skilled map users and six students currently completing a BA in Landscaping Studies in the Centre of Continuing Education. Three of the group were female. The non-experienced group comprised post-graduate students in the Department of Informatics with a balanced distribution of females and males. All participants were volunteers and were paid ten pounds.

Materials: One planimetric map and one contour map each measuring 23 X 18 cm were used. The planimetric map was a reproduction of the Thorndyke & Stasz (1980 pp.141) Town Map. The Contour map was of an area approximately 3sq. miles around the Devon village of Yeoford. The area was selected from Ordnance Survey Explorer Series Map (no.113), scale 1 : 25,000, and provided a similar density of information as the town map but with features located in undulating terrain.

Participants' sketch maps were recorded using specially designed software, TRACE (Cheng & Rojas-Anaya, 2004), and a Wacom Intuos 2™ graphics tablet with an effective working area of 30 x 22cms. This provided a detailed record of the commencement and completion of every pen stroke in the compilation of the sketch map during the recall phase. Information from the graphics tablet was relayed to a monitor, resolution 1280 x 1024 pixels, beside the participant. Sketch map production was recorded from the monitor using a Canon MV850i video camcorder, which also provided a synchronous record of participants' verbal protocols.

Verbal Protocols were obtained using the 'think aloud' technique described by Ericsson & Simon (1993) and analysed using the Hyperesearch™ software programme. A total of twenty descriptions of cognitive processes or memory strategies were selected from the codes originally identified in the Gilhooly et al and Thorndyke & Stasz studies and are listed in Table 1.

Table 1: Codes for procedures employed during encoding and recall of map data.

Code	Definiton
Counting	Counting number of features
Feature Description	Identifying particular aspects of features
Inferring Height	Attributing values of altitude or rates of change of altitude.
Lay Schema use	Use of memory aids during encoding
Memory directed sampling	Returning to specific map locations to identify partially remembered features or their relative locations
Metacognition	Analysis of personal performance on aspects of cognitive processing.
Negative evaluation	Critically evaluating performance or results
Partitioning	Dividing the map into sub units to facilitate the memory task
Pattern encoding	Using geometric or familiar shapes to identify spatial relationships
Positive evaluation	Evaluating personal performance positively
Random sampling	Unstructured identifying of features
Reading Heights	Merely reading as opposed to inferring heights
Reading Names	Reading names as a unitary task
Rehearsing names	Repeated reading of names
Relational encoding	Describing feature location as it relates to other features
Specialist schema	Employment of specialist knowledge to provide enhanced comprehension of the information studied or recalled
Stochastic Sampling	Search pattern partially determined by previous search and not entirely random
Systematic sampling	Directed searching for specific or classes of features
Task reference	Incorporating features of the designated task into the search and encoding processes
Verbal association	Use of word association as a memory aid

Procedure: Participants were tested individually and completed in turn: a ten-item Familiarity with Maps questionnaire; a question Paper Folding test (French, Ekstrom & Price 1963) and; a Rey-Osterrieth Complex Figure copying task (Meyers & Meyers 1995). The Familiarity with Maps Questionnaire was purpose-designed to provide an objective measurement of participants' map skills. The Paper Folding and Rey Complex Figure tasks provided measurements of spatial ability and spatial memory. Participants were then provided with written instructions for the Town Map task. These stated:

'You are about to begin studying a town map. The map will be made available for inspection for one minute, after which it will be removed and you will be asked to reproduce as much as you can remember in the form of a sketch. The map will be available for a further 4 inspections, again for one minute each, until all of the information has been recalled. The aim is to produce a sketch map of sufficient detail to provide a stranger with the information needed to locate facilities within the town. You are asked to 'think aloud' and provide a commentary on what you are attending to as you study the map and again when you copy the information onto your sketch map.'

When the participants had completed five inspections of the map and their sketch maps had been completed they answered eight questions related to information presented on the map. After a two minute break, the full procedure was then repeated for the Contour map. Here the task instructions included:

'The aim is to produce a sketch map with place names suitable for identifying the general layout of the area but which also includes information for walkers of differing fitness levels some of whom may wish to avoid steep hills.'

On completion the participants provided answers to eight questions relating to the contour map studied.

Results

Group means were examined by ANOVA. All α values were adjusted to avoid cumulative type 1 errors. All reported p values < .01 remained significant after bonnferoni correction. Detailed results for each test are provided in table 2.

Scores for the Familiarity with Maps Questionnaire showed that participants in the experienced group were more frequent map users and displayed a deeper knowledge of map symbols than the less experienced group. The groups did not differ, however, in their general spatial abilities when measured by the Paper Folding task nor in their spatial memory performance when measured by the Rey-Osterrieth tracing task.

In the Town Map exercise the groups did not differ significantly in either the quantity of data they recorded from the five map inspections nor in their knowledge of the map when providing verbal answers to the Town Questions on completion of the copying task.

However in the Contour Map task the experienced group recorded significantly more data than the less experienced group during the recall task F(1, 14) = 13.6, p < .003.When the information was sub-divided into information relating to 'features' and information relating to 'contours' the expert group reproduced more information than the novices relating to contours F(1,14) = 5.25, p = .038 but not relating to features F(1,14) = 3.449, p = .084

Unexpectedly, although the experienced group did perform marginally better than the less experienced group on the contour map questions, this difference was not significant This result was surprising because the experts had displayed superiority in their recall of data for contour features and might therefore have been expected to have a greater comprehension of their final sketched map. Further examination of the contour questions revealed that the level of difficulty might have contributed to the generally poor performance of both groups thereby possibly introducing floor effects.

Table 2: Group Differences for each task. Group Means, (SDs) and Significance

Task	Expert	Novice	Sig
Familiarity with maps Q	14.3(1.5)	9.5(2.7)	**
Spatial Ability	5.9(1.9)	6.1(1.4)	
Spatial Memory	25.7(3.4)	24.5(5.4)	
Town Map Data	28.2(3.8)	24.6(3.4)	
Town Map Questions	20.6(11)	14.5(8)	
Contour Map Data	28(4.0)	22(2.4)	**
Contour Map - Features	19.5(4.2)	16.3(2.6)	
Contour Map - Heights	9.0(3.0)	6.0(2.1)	*
Contour Map Questions	8.9(5.5)	6.2(5.4)	

*sig < .05 **sig <.01

Analysis of the verbal protocols was conducted using the Hyperware™ Software. The video and audio recordings were examined for each participant and all instances where the coded procedures listed in Table 1 were employed were identified and entered into the database. Group scores for both map exercises are provided in Table 3.

In the Town Map exercise participants from both groups frequently employed the aide-memoir of 'reading names aloud' when encoding and recalling information. While the expert group recorded a lower mean number of instances (M = 42, SD = 3.46) compared to the less experienced group (M = 50.6, SD = 10.6), these differences were not significant. Similarly the use of 'relational encoding' in the town map task was employed by both groups with almost equal frequency. The experienced group (M = 20, SD = 11.2) recorded more instances than the novices (M = 18.6, SD = 13.3) but again these differences were not significant. For the remaining codes in the Town Map task, there was some evidence of 'metacognition' and 'lay schema use' in some participants' protocols but no group differences were evident for these or the remaining codes. It was noted, however, that for both the 'lay schema' and 'metacognition' individual scores across members of the group were not equally distributed leading to large standard deviations. Group comparisons, therefore, were not considered fully reliable for these codes as they reflected large individual differences within each group.

However with the examination of the verbal protocols for the Contour map a different picture emerged. When the experienced group encoded and recalled the contour data, the participants employed the 'relational encoding' strategy more than twice as often (M = 21.8 SD = 10.1) than the less experienced group (M = 9.7 SD = 4.6) and this difference was significant F (1,14) = 9.43, p < .008.

Similarly, examples of 'inferring height' occurred in the protocols of the experienced group almost twice as often (M = 27.6 SD = 8.4) as in those of the less experienced group (M = 14.5 SD = 4.5). Again the group differences were significant F (1, 14) = 15.07, p < .002.

Table 3: Frequency of occurrence of procedural strategies in Group Verbal Protocols. Mean & (SD)

Town Map

Procedural Code	Expert	Novice	Sig
Reading Names	42.0(3.5)	50.7(10.7)	-
Relational Encoding	20.0(11.2)	18.7(13.3)	-
Lay Schema	10.0(11.3)	5.0(5.3)	-
Metacognition	8.0(2.6)	7.7(8.9)	-

Contour Map

Procedural Code	Expert	Novice	Sig
Reading Names	21.2(9.2)	23.4(8.0)	-
Relational Encoding	21.8(10.1)	9.7(4.6)	**
Inferring Height	27.6(8.4)	14.5(4.5)	**
Metacognition	5.9(2.3)	4.0(2.0)	-
Lay Schema	2.7(1.6)	2.2(1.6)	-
Specialist Schema	4.8(5.4)	.38(.74)	**
Task Reference	2.6(2.8)	1.37(.92)	-
Negative evaluation	2.7(2.8)	1.1(1.5)	-
Positive Evaluation	1.5(1.4)	.13(.35)	-
Partitioning	.76(1.75)	.13(.35)	-
Pattern Encoding	.13(.35)	.25(.46)	-

*sig < .05 **sig <.01

The experts appeared to differ in one further encoding and retrieval strategy by their use of 'specialist schemas'. This verbal protocol code had been defined as 'employing specialist knowledge to provide enhanced comprehension of the information being studied'. Examples included 'we have a spur running down between these two areas of high ground' and 'there are a couple of re-entrants (small valley at the head of a stream) from the East'. The experienced group averaged nearly 5 examples of specialist schema use per participant (M = 4.75 SD = 5.4) while in the non-expert group only two participants employed specialist knowledge and then only on a total of three occasions (M = .375 SD =

.74). Accordingly the groups differed significantly, F (1,14) = 5.0, p < .043. Of interest here however, were the large individual differences as illustrated by the associated high values of standard deviation within group scores. These reflected a large variance in specialist knowledge within the experienced group and highlighted the difficulties in consistently capturing the complex nature of specialist knowledge within a protocol analysis dialogue alone.

The remaining codes occurred infrequently and only in some of the participants' verbal protocols. Accordingly the cumulative scores were too low to provide reliable statistical evidence of group differences.

The low occurrence of the memory strategies of 'partitioning', 'stochastic sampling' and 'memory directed sampling' had been anticipated since the incorporation of a one minute study period into the experimental design had provided a more continuous cycle of information encoding and recall. Where Thorndyke & Stasz had employed a two minute study time and Gilhooly et al a single period of five minutes it could be argued that the task characteristics of these earlier experiments were more suited to a study of spatial and verbal memory rather than an examination of the nature of information processing strategies employed in map reading.

Analysis of the Graphical Protocol data provided detailed values of elapsed time between each pen stroke and a record of distance between completion of each pen stroke and the commencement of the next.

It had been hypothesised that the more experienced map-readers might employ 'information chunking' during information encoding and retrieval and that this might result in faster processing of information during the recall of map data. Accordingly it was expected that experts would process more items of information within chunks and would be expected to have a higher number of short pauses (intra-chunk) and a lower score of long pauses (inter-chunk) than the less experienced group.

Detailed inspection of the Graphical Analysis data was conducted by setting thresholds for pause values in eleven increments between .05 and 20 seconds to identify the frequency distribution of each pause length. The histograms revealed large individual differences between the members of each group but no reliable between-group differences when the individual results were averaged and compared. This result was disappointing since the expert group had transposed more information onto their contour maps than the novices within similar time frames. This suggested that they had processed the information more fluently. Yet while the experts did not appear to reproduce the sketched data with measurably shorter pauses, examination of the move distance data revealed that the experienced group made significantly more additions to their maps at a distance of 500 pixels (approx 15 cms), or more from the previous pen-stroke (M = 7.9, SD = 2.9) in comparison to the less experienced group (M = 4.0, SD = 2.5), F(1,14) = 8.05, p < .01. One interpretation of this result might be that the experts were encoding features that were related spatially or semantically but not necessarily proximally. This explanation would be commensurate with either schema based or 'chunking' theories of expertise.

Discussion

The results replicated those of Gilhooly et al in three important areas. The groups did not differ in their performances for the planimetric map exercise, nor did they differ for feature related information in the contour map task. However they did vary significantly in their processing of contour related information with the experts reproducing more information on their maps than the novice group. Thorndyke & Stasz had reported that when both their high and low spatial ability groups were taught effective procedures, only those participants with good visual memory ability improved in the recall task. However in this experiment the groups differed only in their levels of experience with contour maps. No differences between groups were found in the tests of spatial abilities and spatial memory. Similarly the groups performed equally well for all aspects of the town map task in which the lack of topographical data simplified the task. The superior performance of the experienced group in the recall of detail from the contour map task might therefore reasonably be attributed to differences in the information processing strategies employed by each group for contour related data. Also by incorporating five separate study periods of one minute each, immediately followed by the sketching of map data the experimental design had deliberately biased the task towards a continuous cycle of encoding and recall rather than that of an isolated test of spatial memory.

Analysis of the verbal protocols provided some insights into the differences in information processing evident in each group. While both groups employed the technique of 'relational encoding' in the Town map task, when the contour map was studied only the experts recorded similar levels of usage of this technique. In the novice group instances of 'relational encoding' fell to half those recorded in the planimetric map exercise. It was not clear from the verbal accounts whether or not the novices were affected by the unfamiliarity of the information they were processing or if the extra cognitive processing employed to interpret the map data resulted in a failure to adopt a strategy that had served them well in the earlier task. One confounding variable may have been introduced by the inclusion of three students in the novice group for whom English was not their first language. As the difficulty of the task increased these individuals may have suffered from the increased cognitive resources required to articulate their thoughts in English.

The experts' greater use of cognitive strategies in which they were identified as 'interpreting height' and 'employing specialist schemas' might be explained by their improved ability to integrate contour information with feature information to produce more complex propositional representations. Alternatively the experts may have been constructing a detailed 3D mental image of the area portrayed on their maps. By navigating around their mental images the experts would have had access to information gleaned from their height analysis that then provided another dimension in which to employ ‘relational encoding’. This was evidenced in the verbal protocol statements which included descriptive elements of features imagined within their topographical context e.g. ‘Lower Town is actually higher than Yeoford’. Use of this extra dimension may therefore have contributed to higher scores both for ‘inferring height’ and ‘relational encoding’ in the more experienced group due to their construction of a mental image somewhat richer in detail than the less experienced participants.

This view was further supported by the Graphical Protocol analysis, which indicated that the experts were consecutively encoding and recalling some features more widely dispersed than those recalled by the novices. This again might be interpreted as the experts’ ability to encode individual features not simply proximally related but also according to their topographical, semantic or spatial relationships. Similarly, the less experienced group may have been encoding features only in close proximity to one another and from more narrowly defined locations.

The failure to identify reliable between-group differences in the pause patterns prior to each pen stroke could be attributed to the large individual differences observed in participants of both groups or the variable nature of the sub-tasks within the map sketching exercise. Either or both of these factors may have been sufficient to induce overlapping of the temporal signal values associated with chunk boundaries such that meaningful comparisons between groups were not possible. Also, while the groups differed in their levels of experience as measured by the Familiarity with Maps questionnaire, the difference in levels of expertise was not of the same order as that reported between Chess Masters and novices in the earlier literature on information chunking. Accordingly large effect sizes for any group differences had not been predicted.

These findings nevertheless support the view that experienced map users employ cognitive strategies to process information about features and contours within prototypical configurations based on their familiarity with the information presented. These cognitive strategies are therefore consistent with Template theory and schema based accounts of information processing.

References:

Chang, K., Antes, J., & Lenzen, T. (1985). The effect of experience on reading topographic relief information: analysis of performance and eye movements. *The Cartographic Journal, 22* (2), 88-94.

Chase, W. G., & Simon, H. A. (1973a). The mind's eye in chess. In W. G. Chase (Ed.), *Visual information processing* (pp. 215-281). New York: Academic Press.

Cheng, P. C. H. (1999). Electrifying Diagrams for Learning: Principles for Effective Representational Systems. *Cognitive Science, 26* (6), 685-736.

Cheng, P. C. H., & Rojas Anaya, H. (2004). TRACE User Guide. *(Unpublished Representational Systems Laboratory Report)*.

Cheng,P. C. H. & Rojas Anaya, H. (2007). Measuring Mathematical Formula Writing Competence: An Application Graphical Protocol Analysis. In D.S. McNamara & J.G. Trafton (Eds.), *Proceedings of the 29th Annual Conference of the Cognitive Science Society* (pp.869-874). Austin TX: Cognitive Science Society

Davies, C. (2005). Spatial Expertise and Geographic Information: Towards a Testable Model. Unpublished Manuscript

Egan, D. E., & Schwartz, B. J. (1979). Chunking in recall of symbolic drawings. *Memory & Cognition, 7*, 149-158.

Ericsson, K. A., & Kintsch, W. (1995). Long Term Working Memory. *Psychological Review, 102*, 211-245.

Ericsson, K. A., & Simon, H. A. (1993). *Protocol Analysis: verbal reports as data* (2nd edition). Cambridge MA, USA: MIT Press.

French, J., Ekstrom, R. & Price, L. (1963). Kit of reference tests for cognitive factors. Princeton NJ: Educational Testing Service

Gilhooly, K., Wood, M., Kinnear, P., & Green, C. (1988). Skill in map reading and memory for maps. *Quarterly Journal Of Experimental Psychology, Section A - Human Experimental Psychology, 40A*(1), 87-107.

Gobet, F. (1998). Expert Memory: A Comparison of Four Theories *Cognition, 66*(115-152).

Gobet, F., & Charness, N. (2006). Expertise in Chess. In K. A. Ericsson, N. Charness, P. J. Feltovich & R. R. Hoffman (Eds.), *The Cambridge Handbook of Expertise and Expert Performance*. New York: Cambridge University Press.

Gobet, F., & Simon, H. A. (1996). Templates in Chess Memory:A Mechanism for Remembering Several Boards. *Cognitive Psychology, 31*, 1-40.

Groen, G. J., & Patel, V. L. (1988). The Relationship between Comprehension and Reasoning in Medical Expertise. In M. T. H. Chi (Ed.), *The Nature of Expertise*. Hillsdale:NJ: Lawrence Erlbaum.

McGuinness, C. (1994). Expert/novice use of visualization tools. In A. M. MacEachren & D. R. F. Taylor (Eds.), *Visualization in Modern Cartography* (pp. 185-199). Oxford: Pergamon - Elsevier Science Ltd.

Meyers, J.E., & Meyers, K. R., (1995). Rey Complex Figure Test and Recognition Trial. Lutz, Fl:Psychological Assessment Resources, Inc

Moss, J., Kotovsky, K., & Cagan, J. (2006). The Role of Functionality in the Mental Representations of Engineering Students: Some Differences in the Early Stages of Expertise *Cognitive Science, 30*, 65-93.

Thorndyke, P., & Stasz, C. (1980). Individual differences in procedures for knowledge acquisition from maps. *Cognitive Psychology, 12*, 137-175.

Acknowledgements This study was supported by funding from Ordnance Survey UK and an ESPRC case studentship. The authors wish to thank Clare Davies, Senior Researcher, Ordnance Survey for her valuable contributions to this project.

Appendix 2 Participant Consent form for Experiment 1 & 2

University of Sussex
Falmer
Brighton BN1 9QH

Participant Consent form

Purpose:
The purpose of this study is to research map reading techniques

Procedure:
If you agree to take part you will be asked to complete the following:
1. A short questionnaire relating to map reading experience.
2. A short task related to paper folding.
3. A tracing task.
4. Two map reading exercises.

The total time for the study is approximately 50 mins. You will be paid £10 when you have completed all the tasks.

Voluntary nature of the study/ Confidentiality:
Your participation in this study is entirely voluntary and you may refuse to complete the experiment at any point of the procedure. You may also stop at any time and ask the researcher any questions you may have.
Audio and video recordings of the monitor screen will be made during the map tracing exercise. By signing the consent form you are also authorising these recordings to be used for presentational purposes. However your name will never be connected to any of the results and information enabling identification of participants will not be included in any reports. The data collected will only be made available to those engaged on the project.

Questions and contacts:
At this time you may ask any questions you may have regarding this study. If you have any further questions at a later date you may contact Dr Blay Whitby at the School of Science and Technology, University of Sussex.

Statement of consent:
I have read the above information. I have asked any questions I may have had regarding the experimental procedure and they have been answered to my satisfaction. I consent to participate in this study.

Name of participant _______________________ Date_______________

Signature of participant_______________________

Thank you for your participation

Appendix 3 Familiarity with maps questionnaire – Experiment 1 & 2

Familiarity with maps questionnaire

Participant no:_____ Male/Female Age______

Please circle your answer

1. How skilled are you at navigating to an unfamiliar destination using a standard road map.

   a) Very skilled b) Moderately skilled c) Not skilled

2. How comfortable are you in identifying your location in a strange town by use of a street map.

   a)Very comfortable b) Not very comfortable c) Uncomfortable

3. How familiar are you with Ordnance Survey contour maps (eg. Landranger and Explorer series)

   a) Very familiar b) Not very familiar c) Unfamiliar

4. Do you engage in any recreational pursuits involving map reading (eg. Orienteering, hill-walking or car rallying)

   a) Frequently b) Occasionally c) Never

5. Do you use maps in your present employment / area of study.

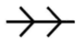
   a) Frequently b) Occasionally c) Never

6. On a Landranger map what does the symbol  represent

   a)Footpath b)Byway c) Bridleway

7. On a Landranger map the symbol  represents a

   a)Hotel b) Hospital c)Heliport

8. On an explorer map what does the symbol  depict.

   a)Gradient greater than 1:5. b) Gradient less than 1:5 c)Pipeline

9. On a Landranger map what is denoted by the symbol 

   a)Embankment b) Cutting c) Tunnel

10. On a Landranger map what is represented by this symbol 

    a) Windpump b) Windmill c) Wind generator

Appendix 4.1 Paper Folding Test Instructions

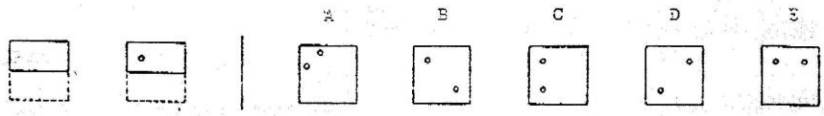
MAY-04-1993 16:00 FROM IUP TO 01144316504587 P.02

Name ____________________

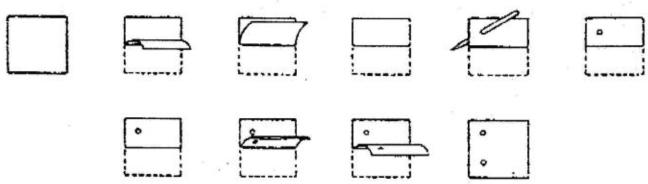
PAPER FOLDING TEST — VZ-2

In this test you are to imagine the folding and unfolding of pieces of paper. In each problem in the test there are some figures drawn at the left of a vertical line and there are others drawn at the right of the line. The figures at the left represent a square piece of paper being folded, and the last of these figures has one or two small circles drawn on it to show where the paper has been punched. Each hole is punched through all the thicknesses of paper at that point. One of the five figures at the right of the vertical line shows where the holes will be when the paper is completely unfolded. You are to decide which one of these figures is correct and draw an X through that figure.

Now try the sample problem below. (In this problem only one hole was punched in the folded paper.)



The correct answer to the sample problem above is C and so it should have been marked with an X. The figures below show how the paper was folded and why C is the correct answer.



In these problems all of the folds that are made are shown in the figures at the left of the line, and the paper is not turned or moved in any way except to make the folds shown in the figures. Remember, the answer is the figure that shows the positions of the holes when the paper is completely unfolded.

Your score on this test will be the number marked correctly minus a fraction of the number marked incorrectly. Therefore, it will not be to your advantage to guess unless you are able to eliminate one or more of the answer choices as wrong.

You will have 3 minutes for each of the two parts of this test. Each part has 1 page. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

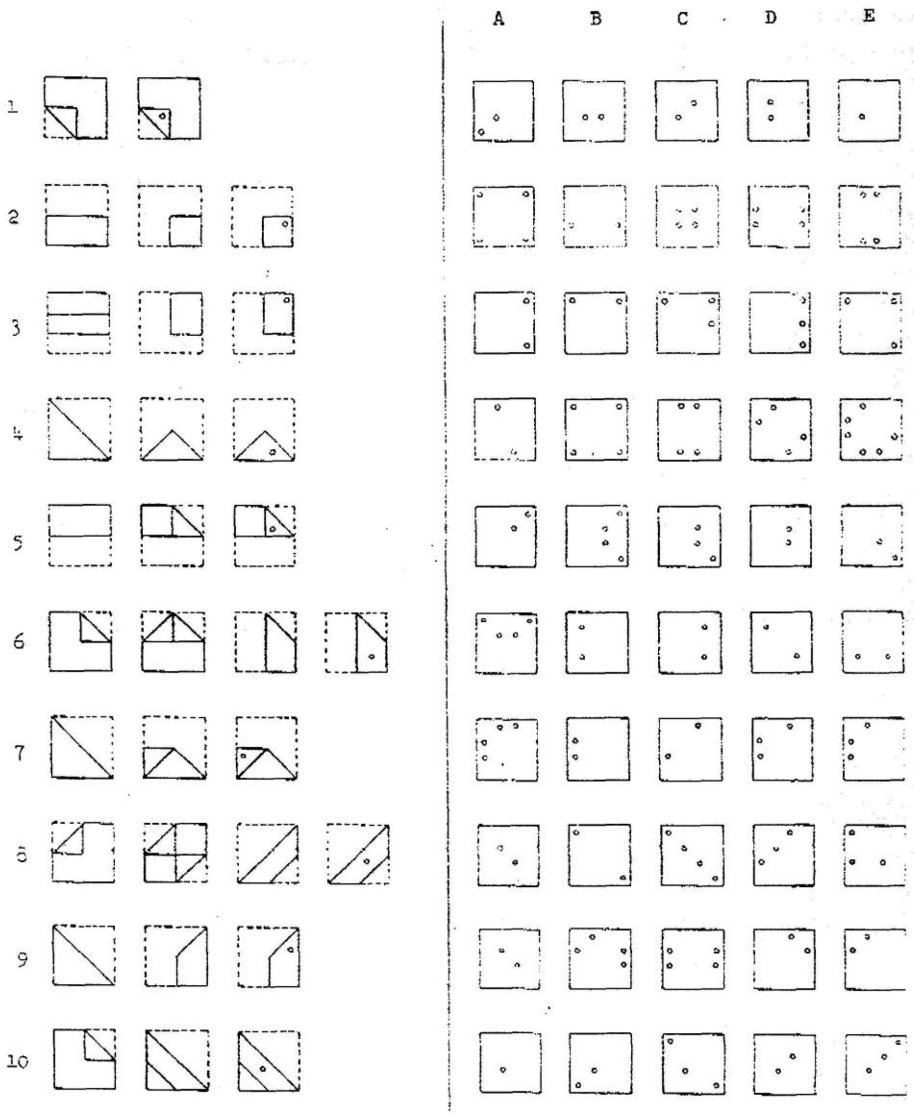
RECEIVED FROM 508 663 9569 05.04.1993 20:59 P. 2

Appendix 4.2 Paper Folding Test

MAY-04-1993 16:01 FROM IVP TO 01144316504587 P.03

Page 2 VZ-2

Part 1 (3 minutes)



DO NOT GO ON TO THE NEXT PAGE UNTIL ASKED TO DO SO.

STOP.

:CEIVED FROM 508 663 9569 05.04.1993 21:00 P. 3

Appendix 5 Town Map

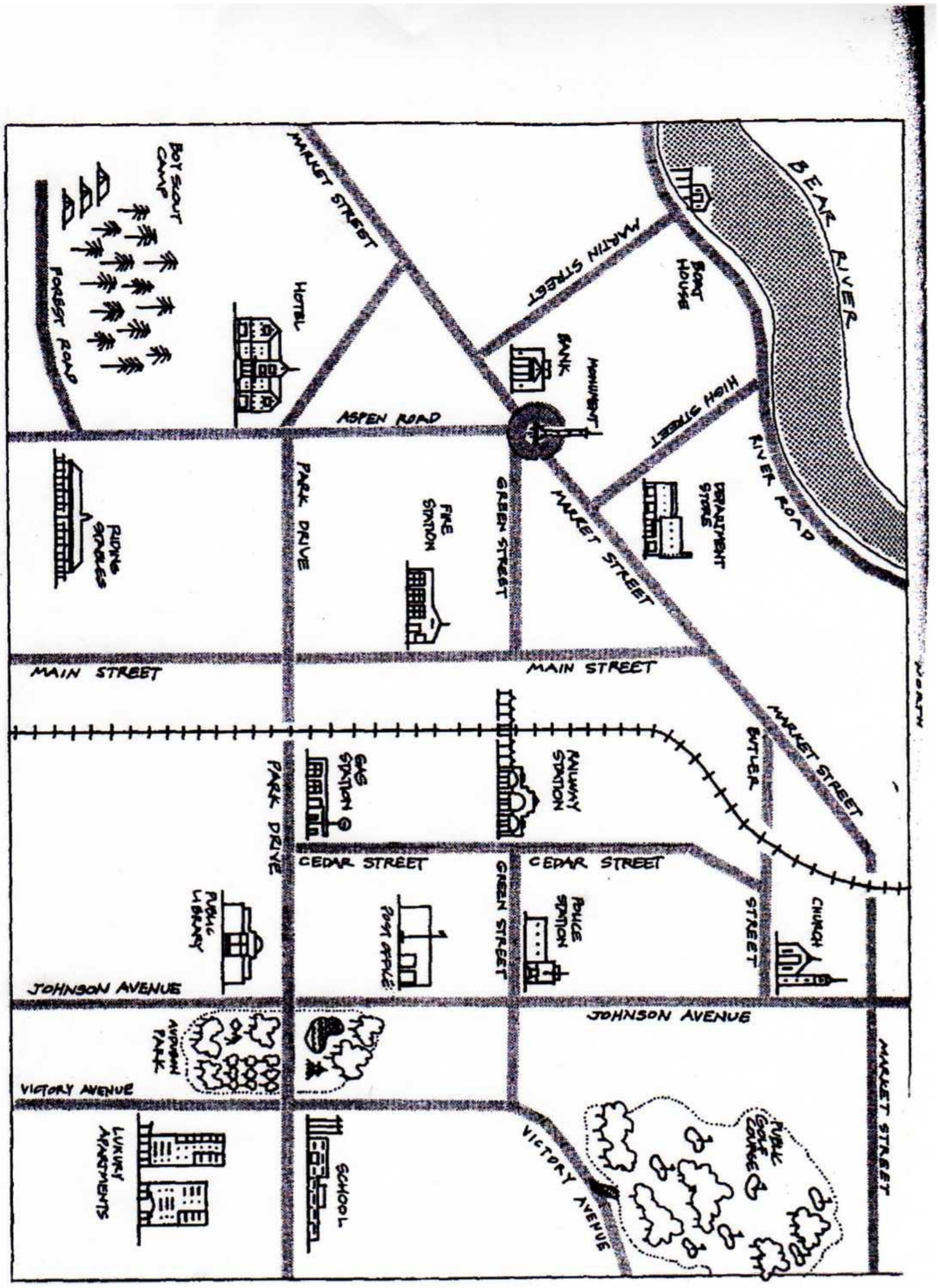


FIG. 1. Town Map.

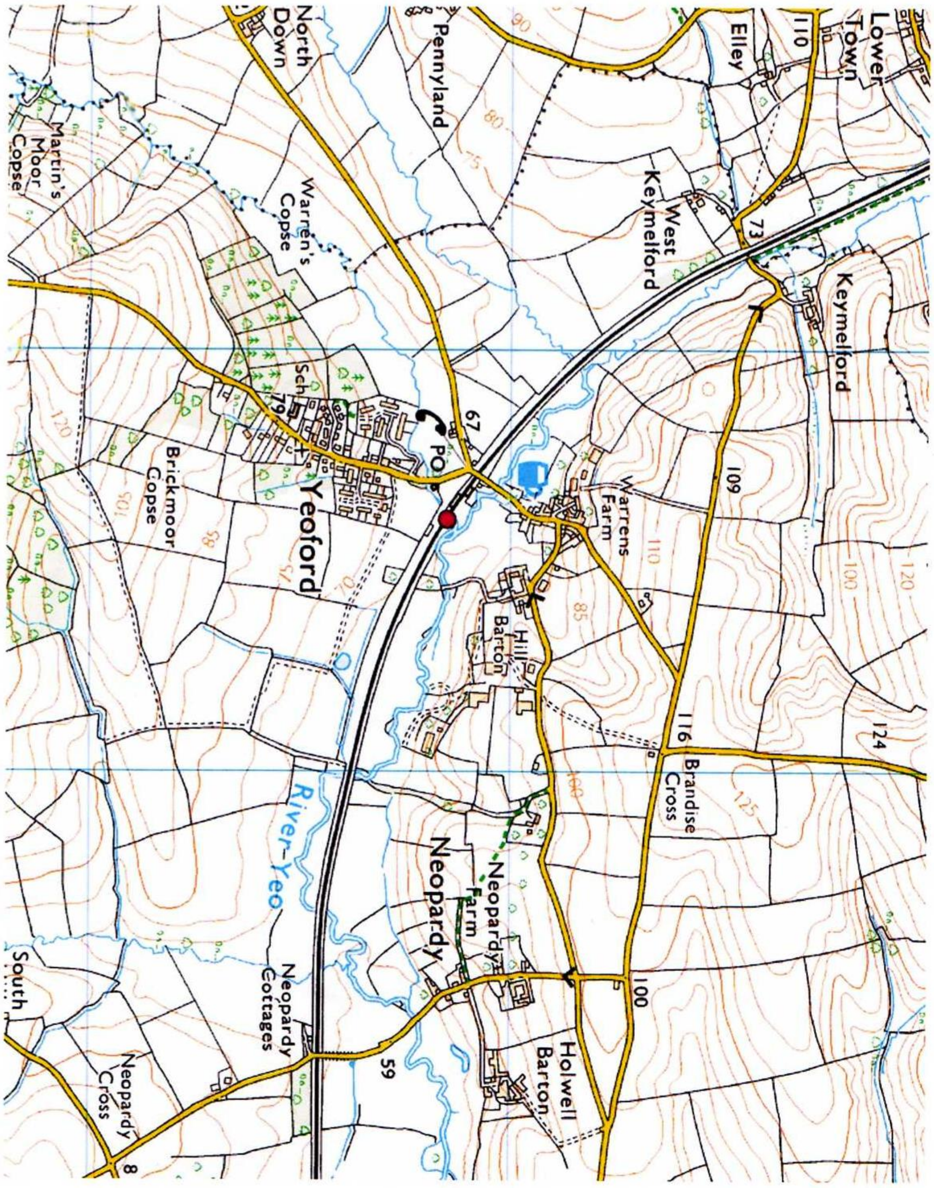
Appendix 6 Town Map Questions

Town Map Questions

Please circle your selected answer and indicate your confidence in your answer on a scale of 1 to 5 where 1= really not sure and 5=supremely confident. .

1. On which avenue is the school? Victory or Johnson . (Conf……)
2. How many intersections are there between the hotel and the public library? Two or three. (Conf……)
3. Which is closer to the monument, the railway station or the riding stables? (Conf……)
4. Which building is at the intersection of Cedar Street and Park Drive? The Gas station or the Post Office. (Conf……)
5. Is the boat-house at the end of High Street or Martin Street? (Conf……)
6. Is the railway to the left or right of Cedar Street? (Conf…..)
7. Is the road beside the river called Bear Road or River Road? (Conf……)
8. Is the Police Station at the intersection of Johnson Avenue and Green Street or Cedar Street? (Conf…..)

Appendix 7 Contour Map



Appendix 8 Contour Map Questions

Contour map questions.

1. Does the road from Keymelford to West Keymelford cross under or over the railway. Conf.
2. Is Yeoford at a greater elevation than Lower Town. Conf.
3. Is Keymelford visible if you are located at Warrens farm. Conf.
4. Does the road at Neopardy cottages cross over or under the railway. Conf.
5. If walking South from Warrens Farm which road is the steeper climb ,through Yeoford or North Down. Conf.
6. Is the road from Hill Barton to Warrens farm steeper than the road from West Keymelford to Lower Town. Conf.
7. Is the highest hill to the South or North of the railway line. Conf
8. How many times does the railway cross the river. Conf.

Appendix 9 Participant Consent Form - Experiments 3a & 3b

University of Sussex
Falmer
Brighton BN1 9QH

Participant Consent form

Purpose:
The purpose of this study is to research map reading techniques

Procedure:
If you agree to take part you will be asked to complete the following:

1. A short questionnaire relating to map reading experience.
2. A map reading task in which you will be asked to provide a commentary while you complete the task.
3. Two further short map reading tasks without verbal commentary.

During the map reading phases your eye movements will be tracked (unobtrusively) using remote sensors sited below the screen you will be studying.

The total time for the study is approximately 55 mins. You will be paid £10 when you have completed all the tasks.

Voluntary nature of the study/ Confidentiality:
Your participation in this study is entirely voluntary and you may refuse to complete the experiment at any point of the procedure. You may also stop at any time and ask the researcher any questions you may have.
The tasks will be monitored with audio and video recordings during the map exercises. By signing the consent form you are also authorising these recordings to be used by the research team during the data analysis. However the data collected is coded with participant numbers and your name will not be connected to any of the results and information enabling identification of participants will not be included in any reports. The video and audio recordings will be made available only to those researchers engaged on the project for the purpose of data analysis and will not be included in the formal report nor in any subsequent presentations.

Questions and contacts:
At this time you may ask any questions you may have regarding this study. If you have any further questions at a later date you may contact Professor Peter Cheng at the School of Science and Technology, University of Sussex.

Statement of consent:
I have read the above information. I have asked any questions I may have had regarding the experimental procedure and they have been answered to my satisfaction. I consent to participate in this study.

Name of participant ________________________ Date________________

Signature of participant________________________

Appendix 10.1 Map Experience questionnaire Experiment 3a & 3b

Participant Number………. Male / Female Age (optional)……….

Please circle your answer

1. How skilled are you at navigating to an unfamiliar destination using a standard road map

a) Extremely skilled b) Very skilled c)Moderately skilled d) Somewhat skilled e) Not at all skilled

2. How familiar are you with Ordnance Survey contour maps (eg. Landranger and Explorer series)

a) Extremely familiar b) Very familiar c) Reasonably familiar d) Not very familiar e) Not at all familiar

3. How easy do you find identifying your location in an unfamiliar town using a map

a) Very easy b) Quite easy c) Reasonably easy d)Not very easy e) Hard

4. How often do you use maps in your present employment

a) All the time b) Quite regularly c) Occasionally d) Hardly ever e) Never

5. How many years have you been using street maps

a) More than 40 b) 25 to 40 c) 10 to 25 d) 4 to 10 e) Less than 4

Appendix 10.2 Map Experience Questionnaire Experiment 3a & 3b

6. How many years have you been using contour maps.

a) More than 40 b) 25 to 40 c) 10 to 25 d) 4 to 10 e) Less than 4

7. How often do you use a map for recreation activities (eg. Cycling, orienteering, walking)

a) Very often b) Quite often c)Occasionally d) Seldom e) Never

8. How often do you use other forms of maps (ie Admiralty charts, Ski-maps)

a) All the time b) Quite regularly c) Occasionally d) Almost never e) Never

9. When giving route or destination instructions are you likely to draw a map rather than list the route instructions

a) Extremely likely b) Highly likely c) Quite likely d) Not very likely e) Very unlikely

10 At what age do you recall first using a map

a) Under 5yrs b) 5 to 7 yrs c) 7 to 10 yrs d) 10 to 15 yrs e) older than 15