The contribution of geographic information systems and imagery to military learning of new environments

by

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This thesis reports a series of three experiments undertaken to investigate whether the use of geographic information systems (GIS) and imagery toolsets improved or accelerated learning about new environments in military personnel. The first experiment took place within a large rural environment over six days, and the second took place in an urban environment in a single session lasting three hours. Each of these experiments compared the use of GIS and imagery with the use of maps only. All participants were able to have direct navigational experience of the environment. The final experiment aimed to investigate the effect of specialisation on the components extracted from real scenes. The results showed that there was evidence of learning exhibited in both environments, and the use of GIS and imagery did provide an increase in the number of landmarks identified, and the number identified on sketch maps produced by the participants. However, there was little improvement in the accuracy of landmark location from GIS and imagery learning over learning with maps. In general there was a high degree of individual variability in performance for the spatial tests, and it is concluded that this variability masked effects of the experimental conditions. Those participants with specialist technical or geographic experience were able to identify more components and more details from the images presented than participants from other backgrounds. It was concluded that the use of GIS and imagery provide useful additional information to that provided by mapping, and appeared to increase user confidence.
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GLOSSARY

GIS Geographic Information System – a software application to present and manipulate mapping and imagery on a computer

SNCO Senior Non-Commissioned Officer (rank of Sergeant and above)

Team in this context, a team is four persons operating together

Group in the context of this research is a collection of twelve personnel working in three teams of four.
Chapter 1

INTRODUCTION

Background

General background

This thesis considers the contribution of geographical and imagery aids to learning new environments for the military user. The military user has a real requirement to be able to rapidly and accurately learn about a new environment, and this need covers both urban and rural situations.

Considerable research has been undertaken into the effect of such tools on learning for the naive, civilian (usually academic and/or student) user; but little research is aimed at the specific case of the military users.

It is possible that the military users form a particular case, since the academic background of the individuals is variable (unlike the academic background of students). Furthermore, the ability to read and interpret map data is a specific element of leadership training within the military organisation, again unlike the general training for the majority of students.

For the military user, depending on their role within the organisation, there may be a particular drive for learning about the environment, particularly new environments. This drive is determined by the actual or perceived danger to the team from the potentially hostile inhabitants of that environment. This drive is difficult to replicate with laboratory or field conditions. A second reason for the acquisition of spatial knowledge is the need to conduct activities within that environment, and this is in common with everyday non-military situations; people need to be able to find the necessary landmarks (for example, shops, doctors, schools etc) within their environment to be able to conduct normal tasks of living and to work out routes to and between these landmarks.
Research

The research undertaken within this programme builds on the considerable body of published literature (which is covered in more detail in chapter 2), to investigate the use and utility of practical options for the military user. The military use requires a solution that can provide information rapidly and in an easily assimilated format. The information sources used need to be easily updated and the accuracy confirmed. This requirement for practicality drove this research programme into personal computer based solutions, and commercially available imagery and information systems, rather than complex virtual reality systems.

When learning about a new environment, in general, people can use maps to start an understanding, and typically will build up spatial knowledge by experience of travelling through and within the environment. This option of direct experience is not always available initially to military, and therefore a system or toolset that will assist these users in acquiring this knowledge would be beneficial.

However, procurement of such a system needs to be based on solid and confirmed benefits, and therefore there is a need to understand how these systems would accelerate or improve learning in typical military situations. Also not fully explained in the available literature to date is any effect of attempting to use this type of tool in a fully rural environment, and this is an important case to consider. There is the potentially obvious difference in the availability of distinctive landmarks between the two situations (urban and rural) to be considered.

As military tasks can take place in either rural or urban situations, there is a requirement to compare the use of GIS and imagery tools in rural and urban areas, for the military participant there may be differences in the way in which such tools are set up and used which may be relevant.

The military participants require a high degree of spatial information about the area in which they may undertake activities. Although maps and global position system devices are available, learned knowledge of the environment
with good recall is a valuable element of the successful completion of their tasks. As defined in the current literature, the military require a combination of both route and survey knowledge: they require a recall of a sequence of landmarks to define accurately the route that they are following and to identify deviations from planned routes or alternatives to that route should they be required. Survey knowledge of the inter-relationships between routes and landmarks, and the distances involved, is also a requirement to successfully complete a task.

At the time of conducting this experiment, military personnel learn spatial knowledge about new environments principally using maps of varying scales. Some aerial imagery (for example GoogleEarth™ type imagery) may be available to assist learning. This learning can be by rote individually or collectively by presentation from experienced members of the group.

It was stated that with current technology available “there had to be a better way” than merely using maps. Although, as can be seen from the literature and the tools used in these experiments, this statement did beg the question: are these GIS and imagery toolsets better than using a map for military personnel?

Therefore, a number of questions were identified that could be answered by a research programme of this type. Firstly, does the use of GIS and Imagery accelerate or improve spatial knowledge overall when compared to map learning alone? Is there a difference in knowledge acquisition in urban and rural environments in both map learning and virtual environment learning conditions? Is there a difference in the type of knowledge (route or survey) acquired in each environment for each type of learning tool? Is there an effect of training and experience on the acquisition of spatial knowledge?

**Overview of the structure of the thesis**

Chapter two provides a summary of some of the background literature to this subject: there is a considerable body of literature available and this chapter outlines the most relevant to the questions posed.

Chapter three provides a description of the imagery and geographic information systems used as the toolsets for the experimentation.
Chapter four summarises the experimental designs and the terminology used in this research.

Chapter five discusses the first experiment conducted for this research programme: that conducted in the rural environment, and summarises the remaining questions to be answered leading from this experiment.

Chapter six discusses the second experiment in this series: that conducted in the urban environment. This experiment aimed to discover whether there was benefit to using imagery toolsets in the urban environment and to overcome some of the confounding factors identified in the rural experiment.

Chapter seven discusses the final experiment in this research: the analysis of the image components identified by participants originating from different military specialisations. This experiment was conducted as a result of findings in one of the test battery administered in the rural experiment.

Chapter eight provides a general discussion of all the results obtained.

Chapter nine summarises the research undertaken and highlights the conclusions and recommendations for further research.
Chapter Two

LEARNING NEW ENVIRONMENTS FROM MAPS OR VIRTUAL ENVIRONMENTS

Background

Much research has taken place to investigate the way in which humans learn about the physical environment around them, and how navigational aids and cartographic maps are used to assist this learning. A summary of some of the relevant research in this area is presented in this chapter.

Definitions

The term virtual environment is used in this thesis to define those technologies which allow the subject to access a model of the environment; that model can be a series of still or panoramic images, a video or a true 2.5 or 3D model of the environment.

Route knowledge

Route knowledge (Thorndyke & Hayes Roth 1980) is defined as the knowledge learned by experience encoding distances and orientation with respect to unseen objects. This knowledge is also defined to include the details about the individual landmarks or key points required for the military operation. Hirtle & Hudson (1991) classify route knowledge as the "knowledge of sequential locations with the knowledge of general interrelationships".

Survey knowledge

Survey knowledge is defined in many references (eg Thorndyke and Hayes-Roth 1982 or Golledge, Ruggles, Pellegrino and Gales 1995) as the overview of the environment, "the Birds' Eye view". Survey knowledge is assumed to be the highest or most complete level of knowledge concerning the environment, because this level of knowledge requires an internal manipulation of the elements of the spatial knowledge. The authors discuss the importance of Critical
Anchor Points that depend on the hierarchical dominance of certain cues in relation to each other. This research also investigated the impact of geographical training on the acquisition of spatial knowledge. The experiments used a fictional building as the novel environment and participants were college staff or students. The results did not prove the superiority of map learning, although navigational learning was through the medium of computer simulation.

Survey knowledge (Thorndyke & Hayes Roth 1980) is defined to mean the knowledge learnt from a map encoding global spatial relations. Hirtle & Hudson (1991) define what they call configurational knowledge as the ability to “generalise beyond learned routes and locate objects within a general frame of reference”.

**Learning environments from maps**

Much work has been carried out to assess the impact of map learning on the spatial knowledge of subjects (Thorndyke & Hayes-Roth (1982), Abu-Ghazaleh (1996), Bone and Lintern (1999), Gale, Golledge, Pellegrino and Doherty (1990), Hirtle & Hudson 1991, McNamara, Ratcliff and McKoon (1984), Richardson, Montello and Hegarty (1999), Rossano, West, Robertson, Wayne and Chase (1994), Thorndyke and Stasz (1980)). Much of this research has compared learning new environments from maps with learning from direct experience. In general, the available research identifies that map learning leads to better acquisition of survey knowledge, whilst direct experience leads to better acquisition of route knowledge.

**Learning medium**

Many of these studies reviewed compared map learning with direct experience of some type, for example, Thorndyke and Hayes-Roth (1982) compared direct navigation experience with map learning. In an alternative experimental design Gärling, Böök, Lindberg, and Nilsson (1981) compared using a vehicle to drive their participants through an area compared with walking through the area. Direct experience was shown to lead to the acquisition of route knowledge (Thorndyke and Hayes-Roth 1982) and better performance on orientation tasks. Map learning was shown to lead to the acquisition of survey knowledge.
knowledge (op cit) and better performance at distance estimation tasks. Comparison of maps with a slide show for learning the environment (Hirtle & Hudson 1991) showed that subjects learning from a map had better configurational knowledge than those learning from the slides. There were considerable differences in the configurational knowledge within the group learning from slides.

In contrast, Gärling et al (1981) showed that participants being driven through the route acquired knowledge faster than those walking. In this experiment landmark information was presented to the participants during their tour. It was found that on a recall task where participants were asked to order the landmarks, acquisition of this level of knowledge was very rapid (near perfect performance after one tour), however accuracy of location of those landmarks was not perfectly accurate.

The length of exposure to the environment has also been shown to affect the learning: Thorndyke and Hayes-Roth (1982) showed that there was a difference in performance between the two groups that depended on the length of exposure to the environment, for moderate exposure map learning is better for distance estimation and navigation learning is better for orientation. However these differences in performances are diminished with prolonged exposure.

The learning media planned for this research involves a combination of direct experience and either map or virtual environment learning. From the literature therefore, it can be expected that the participants will acquire survey knowledge from the maps and route knowledge from the direct experience. It would be expected that the control groups (with maps only) will perform better at distance estimation tasks.

Memory

In many cases from the previous literature, participants are required to learn environments, and their recall of positions, landmarks and relationships is then tested. The acquisition of knowledge and memory for spatial information is therefore important. Kinnear and Wood (1987) studied memory for topographic contour maps using teenaged schoolchildren. They showed that there is strong
evidence that those participants who were asked questions concerning the map during learning would remember more efficiently than those who had learned passively. They showed no evidence that formal geography training had an effect on performance. This is an important finding for this research to verify, since the way in which the military prepare for tasks involves an amount of passive learning.

Taylor and Tversky (1992) investigated the use of maps for learning about an environment; participants were told that they would be asked to reproduce these from memory. In this research, the descriptions of the maps was a dependent variable, and could be scored for recall order or the order or landmarks. Participants were again students and the environments were fictitious maps created on a computer. In this research the participants' recall was shown to be excellent, with greater than 90% recall of landmarks. Cluster analysis was used to characterise the organisation of the landmarks, and this research showed that the organisation was similar across maps and descriptions of similar environments.

McNamara (1986) drew on previous research and summarised three classes of theories about spatial representation: non-hierarchical theories (stating that spatial relations are mentally represented in propositional networks, for example routes rather than survey knowledge), strongly hierarchical theories (stating that different regions of a representation are stored in different branches of a mental “graph-theoretic” tree). The hierarchical theories can be strong (where spatial relations must be inferred from overarching spatial knowledge) or partial (which allows spatial relations to be encoded). Experiments were undertaken to determine which of the three classes of theory best fit the data. The participants either learned environments through direct experience or maps, and were given a recall and direction judgement test. Results from the experiments conducted supported the partially hierarchical theories.

Map clutter

Many maps of real environments are cluttered with a variety of information contained within. MacEachran (1995) discusses issues surrounding maps, map styles and the production of maps. However, the impact of distortion and clutter
on the ability to learn from a map remains an important consideration. Thordyke (1981) undertook a series of experiments to investigate the distortion effects of map clutter on participants' estimates of distance in an environment. These were, with one exception, fictitious maps. Thorndyke showed that the presence of other key points along the route increased the distance estimate of that route. Thorndyke postulates an analogue timing model to explain these findings. This has a relevance to the planned experiments for this research, since the routes planned for learning are complex with a series of key points to be learned.

Map style

In addition to distracting factors contained within the map, such as clutter, some authors: Devlin and Bernstein (1997) and Rossano and Morrison (1996), have shown an effect of different styles of map on learning.

They investigated the effect of differing map styles on wayfinding; varying level of detail of the map, varying the location of identifying information on the map and using either colour or black and white maps. In these experiments participants were from a range of backgrounds, although predominantly of college age range. They found that participants performed tests faster if learning from a map with labels attached to landmarks, rather than in a legend and that those reporting to be left handed made fewer errors. Males were found to be faster than females in identifying paths for the simulated wayfinding task.

Rossano and Morrison (1996) investigated map structure and the impact of this on the acquisition of knowledge. The framework or structure of a map, or lack of it, affects ability to create a cognitive map and then place elements in this spatial context. It appears that learning is a hierarchical process, with elements placed within an overall context. The study used two types of map: a normal map and a pictorial representation of the area, and represented a fictitious military base. The spatial tests required the participants to imagine themselves at a point on the map, facing a particular direction and then indicate the direction to another element. A second experiment required participants to create map drawings. The results showed that elements at the periphery of the map were better learned and reproduced. It is concluded from this research, that there is difficulty in cohering maps into overall images.
Both MachEachran (1995) and Rossano and Morrison (1996) conclude that elements at the periphery of a map were better learned, which has important implications for the proposed research for this thesis. Traditional maps (for example Ordinance Survey in the United Kingdom) are large in size, although of varying scales and therefore covering various sizes of environment. For the maps that will be used in this study, A0 or A1 size maps will contain a large amount of information and therefore from this research, landmarks located centrally in this structure are likely to be less well recalled.

Holahan and Sorenson (1985) investigated information processing to explore imageability. These experiments used recognition tasks to focus on three levels of salience and organisation of road networks (unorganised, organised and control). Organisation was defined as simplicity and symmetry. The findings indicate that organisation is critical to a highly imageable environment and this reduces the time for identifying salient errors.

As the environments to be used in the research for this thesis are real environments, the mapping to be used will be real mapping. For the size of environments to be used, it will not be possible within the resources of this research to create new mapping for the participants. Therefore the analysis of the results obtained will need to take account of the impact of clutter and map structure on the performance of the participants.

Knowledge acquisition

A number of studies have investigated the way in which participants acquire knowledge about an environment, and how this is encoded for later recall. This acquisition and encoding process appears to involve an integration of the elements (Golledge, Dougherty and Bell 1995).

Hirtle and Jonides (1985) investigated the organisation of landmarks within the cognitive maps of a natural environment. Their hypothesis suggests that other information concerning a landmark and not only Euclidean information will influence the cognitive mapping of landmarks. Their research concerned the effects of hierarchies and barriers on cognitive maps. Of particular relevance to the topic of this thesis is that characterising mental representations as simple
Euclidean relationships is flawed. As with the environments for this thesis, the environment in Hirtle and Jonides research was a natural one, that had not been artificially constructed. The results were analysed using ordered tree algorithms. This research showed that both spatial and non-spatial information were included in participants' cognitive mapping and that non-spatial information is hierarchical in nature.

McNamara et al (1984) tested how spatial knowledge acquired from maps is cognitively mapped, in particular whether the cognitive map distance between cities would be dependent on route or Euclidean distance. The results showed that route information had a special status in cognitive mapping. If locations were close together in both route and Euclidean distance then these primed each other in recall tasks, and that this priming was significantly stronger than locations only close in Euclidean distance. This is important for the rural research experiment where landmarks may be sparse and where the combination of route and Euclidean distance may not be close together.

Hirtle and Mascolo (1986) investigated the effect of altering labels attached to points on spatial representation. Participants for this research were undergraduates. In an initial experiment participants sorted names of potential landmarks on the likelihood of their proximity in a typical environment. The clusters identified in this task were used as the basis for further experimentation. In further experiments, artificial maps were created such that spatial relationships and labelling relationships were identifiable for 10 points. The research showed that the labels applied to points did affect the mental representation of landmarks and that this affects the participants' memory. It appears that spatial and non-spatial information are not encoded separately. This study provides further evidence that the clustering of landmarks is critical in the mental representation of an environment.

Schneider and Taylor (1999) used maps loosely created from actual urban environments and descriptions varied according to level of detail presented and whether route or survey. Participants were college students. They found that those presented with survey information drew more maps in free recall tests. Providing superfluous detail in descriptions caused greater inaccuracy in
participants' responses. A second experiment investigated type of information necessary for wayfinding. Participants were found to take notes on path information on first listening to a route description, and to take down supplementary information on a second.

Lloyd and Heivy (1987) have studied systematic distortions in urban cognitive maps. Systematic distortions occur because either information is incorrectly coded or completely missing. Incorrect coding can be a function of the length of time taken to create the cognitive map, or the amount of intermediate information. In this study, participants were drawn from the local population, and were familiar with the test environment. Participants were asked to estimate distance between pairs of landmarks, and estimates of direction from one landmark to other landmarks. The findings from this study indicate that systematic distortions in cognitive maps occur as a result of a rotation heuristic (where the true axis of the frame of reference is rotated to some perceived normal, for example a north south axis).

Mou, McNamara, Valiquette and Rump (2004) used a layout of objects within a room to investigate spatial memory. Participants were either asked to imagine they were facing a point and asked to point to another object or asked to imagine the relative angular distance between two objects. The pointing errors produced were overall quite small (less than 50°). The authors concluded that spatial references were not updated during locomotion. Performance in the spatial tests was best when the imagined heading was the same as the heading used in the learning case, or when the participant was actually facing in the same direction as the imagined heading.

Tversky (1983) presented evidence of errors in the memory for real and artificial environments. Participants were college students and were asked to indicate the relative direction of cities. It is posited that memory for absolute location of figures is difficult, and that relative location is actually remembered. Systematic errors were found to occur, even when participants were warned.

From the research reviewed, acquisition of spatial knowledge depends on the organisation of landmarks within the environment (Hirtle and Jonides (1985)), and the interaction between spatial relationships and labelling.
relationships (Hirtle and Mascolo (1986)); that recall is primed if landmarks are close together in both Euclidean and route distances (McNamara et al (1984)) and that systemic distortions in cognitive maps can occur with orientation effects (Lloyd and Heivly (1987)). The presentation of survey information leads to an increase in the production of sketch maps in recall tests (Schneider and Taylor (1999)). Mou et al (2004) showed that locomotion did not update spatial references. For the purposes of this research, the environments will be real environments, and therefore the organisation of the landmarks is uncontrolled, major landmarks are not necessarily related in Euclidean and route distances. In fact for the purposes of this research, route distances can vary considerably, since in the rural environment, the route may well be directly across the fields or following a footpath or byway. This means that the relationship between landmarks and their associated distances may well be a confounding factor in the analysis.

Goals

The purpose behind learning an environment has been shown to affect the outcome of the learning process. Taylor, Naylor and Chechile (1999) investigated the influence of the goal on the ability to acquire spatial knowledge of an environment. Participants were undergraduates and the environment was the top floor of a building on the campus. Spatial knowledge was acquired either by studying maps or navigation. Participants were either asked to learn the layout of the rooms within the building or asked to learn the fastest route between set points. Learning condition was found to be a significant factor in the survey knowledge tests (Euclidean distance estimation), in that map learning provided more accurate responses. For route knowledge tests, participants with navigation experience provided more accurate answers than those with map learning. Spatial goal was found to have an effect on the performance in the tests: route goals led to better performance overall and spatial goals influenced performance on three of the route tasks.

Magliano et al (1995) investigated specified goals for learning aspects of a new environment, in particular participants were asked to learn landmarks, configuration or a route (controls were given no specific instructions). It was
shown that specific instructions to learn landmarks results in no better recall than instructions to learn a route or a configuration. Participants instructed to learn a configuration (i.e., a schematic of the environment) produced fewer landmarks than other conditions.

**Instructions and strategies**

In some of the planned research, it is proposed that specific instructions will be given to guide participants in the learning process.

Rossano and Hodgeson (1994) studied the process of learning from small scale maps. This research used a map of a fictitious country for learning; the map contained different levels of information: provincial level and city level. Participants were given different instructions for learning the map (ad lib, imagery, story and verbal). The results showed that participants organised their learning using the structure of the different levels of information; i.e., there was a global to local learning process. The research did find that the level of recall of capital cities was as good as or better than the recall of provinces. The research also showed the benefits of an imagery learning strategy.

Thorndyke and Stasz (1980) investigated the acquisition strategies adopted by participants for learning from maps. The research used maps of fictitious areas as learning tools. The participants were either students or persons experienced in using maps. The participants were required to reproduce the maps learned. These were scored using “elements” which were defined as a symbol representing a physical or conceptual entity. Performance was variable on this task. The research analysed the verbalised strategy for recall on the map reproduction task and identified two types of attentional procedures: partitioning and sampling. Good learners were found to adopt a more systematic approach than poor learners.

Evans and Pezdak (1980) undertook a series of experiments to investigate the processing of geographic environments. Participants were asked to determine distance ratios for buildings in the campus or for states within the United States of America. A second experiment required participants to determine the accuracy of spatial relationships between these buildings or states. These experiments
showed that direct experience of the environment allows greater flexibility in the processing of the information.

Easton and Sholl (1995) consider the superposition of self-object relations onto a portion of the object to object representational system. In the second experiment of their paper Easton and Sholl used an urban environment familiar to their participants as their test location. In this experiment, participants were taught the locations of the target points and then asked to imagine themselves facing the same direction but in a different place, and to point to the targets. They observed that latency increased and accuracy decreased linearly with translation distance. They concluded that for irregularly structured arrays of targets, participants were using a body centred co-ordinate system.

Peron, Baroni, Job and Salmoso (1985) investigated the effect of verbal detail on memory for places. This study used undergraduates to pass through a small, real environment and recall details. These participants were divided into two groups, with different levels of attention to the details of the environment. In general recall was found to be poor, however the transit time for the real environment was between 8 and 12 seconds. Furniture items were found to be recalled more frequently than structural items.

Curiel and Radvansky (1998) examined the cognitive representation of map information. This research confirmed earlier findings that the method of learning a map affected the map organisation: a pointing group showed spatial organisation and a naming group showed temporal organisation.

Anooshian (1996) reports on diversity in spatial cognition, particularly the differences between landmark, route and configurational knowledge. Anooshian showed that diversity exists in the strategies to acquire spatial knowledge. Specifically that place learning (as opposed to route or learning turns) leads to acquisition of places, and configurational knowledge.

Lutz, Means and Long (1994) investigated a natural setting for spatial memory: that of parking location at work. Participants were college staff, their parking habits over a number of days were observed and recorded. Participants were then asked to plot on a detailed map the location used for parking on each
of the days of observation from memory. Retention was found to be accurate, although accuracy decreased with time. Participants reported a "park in a favourite spot" strategy for remembering the location.

A number of strategies for learning and recall have been described in the literature: park in a favourite spot (Lutz et al (1994)); place learning rather than route learning (Anooshian (1996)), verbal detail (Peron et al (1985)), a verbalised strategy (Thorndyke and Stasz (1980)) and imagery strategy (Rossano and Hodgeson (1994)). Verbalised and imagery strategies were shown to be effective in assisting learning. It is planned to exploit some of these strategies in the second series of experiments to assess whether these strategies assist military participants in learning the environment.

**Wayfinding**

Of the literature reviewed, one paper studied the errors reported in wayfinding in a familiar environment. Williamson and Barrow (1994) studied diaries of errors in way finding maintained by participants over a four week period. Participants were recruited through advertising. The authors classified the errors reported according to nine categories: a wrong turning, a missed turning, a route selection error, a misconception of location, travelled to wrong location, premature exit, return route error, route exit failure and miscellaneous. The authors found that more errors occurred in familiar environments than in unfamiliar environments, but hypothesise that this is due to the greater proportion of time spent in a familiar environment, therefore with greater opportunity for such errors to occur. The most common errors were missed turnings and wrong turnings. The authors identified five causes for these errors: environmental cause, inattention, inadequate knowledge, habit and inadequate cognitive map.

The sources and causes of error in wayfinding will be important to the analysis of this research, since two of the causes of error were found to be inadequate knowledge and inadequate cognitive maps. The errors in wayfinding per se are likely to be less important in this research since orientation actually within the environment is assisted by mapping, but the sources of error are likely to lead to errors in recall of spatial information.
Summary

In summary, learning from maps was found to improve if labels were attached to maps (Devlin and Bernstein 1997) and that map learning overall produced more accurate responses than navigation (Taylor et al 1999). Elements at the periphery of a map were found to be acquired and reproduced more easily (Rossano and Morrison (1996)). Participants were found to organise learning of spatial knowledge according to the different levels of structure within the available information (Rossano and Hodgeson 1994), however for the environments used in this study, organisation of the information from the available mapping and imagery is difficult. The environments do not lend themselves to superimposed organisation, and particularly in the rural environment, there is very little innate structure.

Participants’ performance in these tasks was found to be variable, with some authors finding good performance (for example Taylor and Tversky 1992) and others finding variable or poor performance (for example Thorndyke and Stasz 1980).

Learning from virtual environments

There is a considerable body of research that has investigated the use of virtual environments in spatial learning. In this research, the term virtual environment has been expanded to include all forms of exposure to an environment that does not involve either maps or direct experience; therefore simulations of the environment discussed in this section include video and photographic tours as well as formal computer simulations of environments. The environments used in previous research principally consist of urban environments, small sections of college campus’ or towns or in some cases single buildings.

The evidence is contradictory on whether the use of virtual environments has a positive, negative or no effect on the acquisition of spatial information. Some papers (Condit (1999) and Aretz (1991) describe the methods of displaying such information, and the factors involved in the appropriate design of such tools.
Condit (1999) describes a program to display geologic information (dynamic digital map). This paper describes the salient features of this type of program. Whilst this program was not used for the test material in this research, the principles underlying the Condit tool were applied as far as practicable to the tools used.

**Learning and knowledge acquisition**

Similarly to the body of research investigating the use of maps as learning aids, there are many research programmes using virtual environments either to investigate the spatial learning process or as learning aids. These environments varied in complexity from simple videos or slide shows of a route through to simulations of a more complex urban environment. Principally the environments used (in the literature reviewed for this thesis) were either buildings or small sections of an urban environment.

Richardson, Montello and Hegarty (1999) compared the spatial knowledge acquired from both map experience and virtual environments. Using a simple route with only three landmarks for the virtual environment, alongside a complex two floor real environment for the map environment, Richardson et al, compared the outcome of the various learning methods. This study showed that a complex environment (in this case two floors) showed poor accuracy for those learning from the virtual environment compared to those learning from the real environment. However, data from this study would suggest that, given the same time of exposure to the learning material, the level of spatial knowledge acquired from maps and navigation are equivalent.

Goldin and Thorndyke (1982) compared the effects of actual and simulated navigation on learning environmental information. In this case, the simulation was provided using video film imagery of the environment. This research used undergraduates as participants, learning about a real environment (part of Los Angeles city) in one of two methods (real and simulated navigation). This research showed that for certain types of spatial knowledge, the simulated navigation was as effective or more effective than actual navigation. For recall of landmarks and landmark sequencing, the film group were more accurate than the tour group; however for orientation judgement the tour group were more
accurate. For other measures there were no differences between the groups. On the orientation task, it was observed that neither group performed very accurately. In this experiment, both groups performed equally well at Euclidean distance estimations. This experiment included the addition of supplementary information with the film (simulated navigation) group, and the impact of this was complex. Narrative appears to have degraded performance.

Rossano and Moak (1998) investigated spatial representation acquired from virtual environments, in particular examining the effect of exposure to a model on acquisition of spatial knowledge. Participants were psychology students, and the environment modelled was a small part of a college campus. A comparison between map learning and computer based learning was conducted. They found no significant difference between map learning and learning from virtual environments, when the spatial tests used to measure survey knowledge required participants to estimate relative direction and distance. In conclusion this study found that exposure to virtual environments has a variable effect on participants' performance.

Rossano, West, Robertson, Wayne and Chase (1999) investigated the characteristics of the spatial knowledge acquired from virtual environments. They aimed to see whether participants using a virtual environment acquired route or survey knowledge, and whether with repeated exposure to the virtual environment, participants would acquire survey knowledge. This environment utilised passive movement through the virtual environment, where the route and time was controlled by the computer rather than the participant. The environment was a simulated 3-D display of a section of a campus. Participants were a mix of students and non students. This research found that map learning outperformed virtual environment learning on tests of spatial knowledge. Tests for this knowledge included shape recognition and shape configuration. The results were less conclusive on whether participants acquired route knowledge from virtual environments, and in fact on some tests found that virtual environment learning produced little difference in error rate to map learning. This experiment did not conclusively demonstrate that learning from a virtual
environment over time led to survey knowledge, and the authors conclude that the complexity of the environment is a factor in this type of learning.

Moar and Carleton (1983) investigated the acquisition of route knowledge for two overlapping urban routes. The participants (psychology students) learned the routes through slide presentations of an unfamiliar area. This study was also concerned with sequential versus spatial map representation. Large differences were observed in the scale of participants' distance estimates. This study also found that participants were more accurate in forward directions than backwards. Moar and Carleton postulate a "facing" hypothesis, stating that directional or distance judgements are more accurate in the direction faced. Secondly they postulate an "order" hypothesis which states that new elements of the route are encoded with respect to earlier learned elements. Their findings suggest that the schemata hypotheses (in which it is posited that elements are placed within an overall schema when learning occurs) are oversimplifying the nature of acquisition. It must be noted that this is a laboratory study and therefore only suggestive for real world findings.

Estes (1987) modified a general class of models for categorisation to produce a cognitive distance model. Estes sought to question how "adequately performance can be accounted for, and perhaps even predicted, on the basis of cognitive processes of memory and decision". This study used both undergraduates and other young adults in the university area. The experiment utilised a simulated vehicle travelling on a computer, the speed of this vehicle was controlled by the participant, for each speed level available, there was a predefined probability of delay. The results showed that, although participants did learn the probabilities involved, on average, the performance was not optimal. This decrement in performance was perceived to be due to "imperfect representation of choice alternatives on a cognitive scale of expected distance". This result is interesting since it provides further insight into the encoding of distance, and therefore has an impact on the proposed distance estimation tasks.

Lloyd (1989) compared participants who had created a cognitive map of an environment through a long period of familiarity and navigation with those who had learnt the environment through a cartographic map. Participants were
university students, in the first experiment were required to be familiar with the
test environment, but the second experiment used an artificial environment. This
second environment map used different names to the first experiment, but
distances and directions between landmarks were the same for both
experiments. This study provides data to support the theory that cognitive maps
created through navigation are different from those created through study of
cartographic maps. Participants learning an environment through long familiarity
and navigation were found to be slower in locating landmarks from reference
point, participants learning from a map were faster at this task. Navigation
participants were found to have more errors both absolute and relative, than
map learning participants. Both types of participants were found to produce more
absolute error than relative.

Allen and Willenborg (1998) studied the effect of concurrent activity on the
acquisition of route knowledge. Participants were college students. The task
involved repeating a randomly assigned series of digits from an auditory source.
Half the participants performed this shadowing task whilst watching a video of 61
colour slides depicting a route, with the aim of learning the route. Half the
participants learned the route with no distractions. The concurrent task did result
in a significant performance decrement. Overall performance on the task
requiring verification of the map detailing the route learned was poor.

Anooshian and Siebert (1996) investigated the diversity of spatial cognition
in the acquisition of knowledge of large scale environments, in particular the
contributions of different cognitive processes for scene recognition. The stimulus
was either a video of a route through a building or direct navigation, participants
were taken from a pool of volunteers. This research showed that the process
disassociation procedure was viable for studying spatial cognition, and that this
provides measures for the roles of familiarity and conscious recollection. These
measures were not affected by the method of learning (video or navigation).

Wilson, Foreman, Gillett and Stanton (1997) investigated active and passive
acquisition of spatial knowledge from a virtual environment. Participants were
university students. The research involved both active exploration of a virtual
environment or passive observation of another participant’s active exploration,
and half of each group directly interacted with the computer. No significant differences were found between active and passive exploration, nor between direct interaction with the computer or none. Errors were found to be around 45°. It was concluded that this finding may be due to the complexity of the environment being used. A second experiment aimed to investigate whether active exploration improved wayfinding ability. However no significant differences were found. However, there was large variation in individual performance, and the results of this research imply that any effect is small and difficult to detect.

Peruch, Vercher and Gauthier (1995) used active and passive exploration of a virtual environment to investigate the learning of object positions in a virtual environment. Participants were asked to select the shortest path between two points. Active exploration was found to result in shorter trajectories and better spatial knowledge acquisition. Participant strategies for learning the environment varied.

Complex environments were shown to be poorly learned from virtual environments compared to simple environment (Richardson et al 1999), which would tend to suggest that the use of virtual environments to learn about new, real environments will not assist or accelerate learning. In contrast, however, simple simulations (for example video imagery) were shown to benefit the acquisition of certain types of spatial knowledge (Goldin and Thorndyke (1982)), particularly recall of landmarks and landmark sequencing. For estimation of relative direction and distance of landmarks Rossano and Moak (1998) found no difference between participants learning from a map or a computer simulation.

Some studies observed large differences in performance at spatial recall tasks, for example Moar and Carleton (1983) observed alignment effect in distance estimation tasks, and proposed that such judgements will be more accurate if participants are facing the appropriate direction.

**Accuracy**

Golledge et al, (1993) studied the effect of learning two overlapping routes through an unfamiliar environment. The results showed that the routes could be learned well enough through the slide presentation to enable successful
completion of the spatial tests employed. However the results also showed large
errors in the pointing accuracy, which the authors presume to be due to working
in the unfamiliar environment. Cross route pointing tasks also resulted in large
errors, leading the authors to conclude that different rules are employed for
learning multiple routes to those employed for learning a single route.

Structures and learning

Gopal, Klatzky and Smith (1989) used the “Navigator” tool as a model for
environmental learning. Navigator utilises a hierarchical structure for the
representation of information, with links representing spatial and non spatial
relationships. Navigator implements the learning of route knowledge rather than
survey knowledge. The authors used simulations to understand the implications
of the model structure and processing algorithms. Overall the model re-iterates
the complexity and number of factors involved in environmental learning and
navigation.

Arthur, Hancock and Chrysler (1997) used a number of objects within a
room to investigate the perception of layout. This study used undergraduate
participants in one of three conditions (real environment, virtual environment and
fixed viewpoint). The findings showed that the experience of the virtual
environment does not significantly alter the representation formed compared to
the representation formed from the real environment. However, participants with
a single fixed viewpoint performed better to participants in either of the other
conditions. It is considered that this single viewpoint gave a perspective similar
to that of a map of the layout and previous research has shown that learning
from a map improves distance judgment.

Implementation of the virtual environment

Mou et al, (2004) studied augmented reality, where computer generated
objects are blended with a real world environment. This research considered the
question: should objects move with the user’s body or stay still with respect to
the augmented reality environment; i.e. should the frame of reference for the
user be stabilised with respect to the user’s body or the environment? The results
suggest that naive users have an environment centred frame of reference.
However, this frame of reference can be quickly updated, to allow a user centred frame of reference.

Jansen-Osmann (2002) reports an experiment using a route through a virtual environment to investigate the role of landmarks. This research replicated some laboratory based studies in a virtual environment to evaluate the use of virtual environments for such studies. This research used students as participants. It was concluded that landmarks play an important role in the environment, and that a landmark together with a turn becomes a strategic node for the acquisition of knowledge. It was concluded that the virtual environment provided good corroboration of earlier findings.

Ruddle, Payne and Jones (1999) used maps and other navigational aids to wayfinding in large scale virtual environments. They created guides within the screen showing the position in the overall environment (global display). They discovered that the local and global map display was the most effective aid in a search task within the virtual environment. This allowed participants to locate objects and their own location within the environment. With time, participants’ performance using the global map alone was as efficient as using the local and global map.

Hirtle and Sorrows (1998) developed a prototype tool for locating library sites on a college campus. This aimed to provide spatial, verbal and cognitive information, with supplementary detail such as the location of the room within a particular building and the location of the main entrance of a building. This design has implications for the theoretical basis of navigation and wayfinding, in that supplementary information, if correctly implemented will assist wayfinding.

Howarth and Finch (1999) studied two different strategies for navigation within a virtual environment, to investigate the nauseogenetic effects of each. This has particular relevance to the subject of this thesis, since the virtual environment will be projected to a number of participants and it is important to ensure that nausea is minimised. The participants were university staff or students who had either head movement or hand control to navigate the environment. Reports of nausea symptoms were recorded from this research for both strategies. During the recovery phase, the assessed rating at 10 minutes
post exposure for the head movement condition was higher than the hand control condition. The results support the hypothesis that the head control condition is more nauseogenic than the hand control condition.

Blaser, Sester and Egenhofer (2000) concluded, unsurprisingly, that improved human computer interaction would benefit GIS, since GIS is inherently complex. Some GIS require a degree of inherent knowledge and skills from the user in order to extract the required information.

Moore and Engel (2001) studied the creation of mental models by degrading the available information about objects. Objects were created in grey scale, and either presented in varying complexity or varying rotation. The research showed that participants over the course of the experiments learned to "fill in" the volume or third dimensional information. This shows that expectations play an important role in acquisition of knowledge about the environment.

Alignment

May, Peruch and Savoyant 1995 studied alignment issues on navigation, specifically whether or not the participants were tested facing the same direction as that which they had learned. Participants' knowledge was tested either by map drawing or by description as a means of learning an environment. Navigation through a virtual implementation of the environment showed that misalignment of the learning maps affected the speed and accuracy of navigation. Increasing misalignment decreased speed and accuracy, but no differences were observed between the two encoding conditions.

Metrics and judgement

Witmer and Sodowski (1998) studied participants' judgement of distance in both real and virtual environments. The study required participants to walk to a predetermined point (which was obviously marked in both environments), whilst blindfolded. In the virtual environment, participants "walked" through the environment using a treadmill. In both environments the relative errors in judged distance were small, however in the virtual environment the errors were approximately double those in the real environment. This study used university personnel as participants.
Devlin and Bernstein (1995) studied the effectiveness of seven types of wayfinding cue information on a computer simulation of a campus tour. The seven types of information were: (1) 14 photographs, (2) 14 photographs plus directional text (e.g., turn right), (3) 14 photographs with directional text referring to landmarks, (4) nine screens with directional text, (5) nine screens with directional text referring to landmarks, (6) a campus map with the tour route marked on it, (7) a campus map with the tour route marked and landmarks identified. Males were found to make fewer errors than females on the wayfinding test and showed significantly greater confidence in their wayfinding ability. Males preferred the use of visual spatial cues. Participants presented with either text or plain maps made significantly more errors.

Transfer of learning from virtual to real environments

Wilson, Foreman and Tlauka (1997) investigated the transfer of spatial knowledge learned from a virtual environment to a real environment. This research used college students in one of three groups: a group allowed to explore the environment (a building) freely, a group using a computer simulation to learn the environment and a control group. Testing was conducted in one of two rooms, using half the participants to conduct pointing tests in the real environment and half in the simulated environment. Participants were also asked to create sketch maps of the building. This research showed evidence of learning from the simulated environment being transferred to the real environment.

Bone and Linter (1999) investigated the effect of rehearsal using a flight simulator on the completion of a flight navigation exercise. Participants were experienced pilots with either private pilots licences or equivalent military qualifications. Participants were divided into three groups: guided rehearsal, unguided rehearsal and map study; the guidance consisted of a red line marking the route through the simulator. The research found that unguided rehearsal was better preparation than map study and that guidance had a negative effect on navigational performance in the spatial tests.
Summary

Many of the previous research studies have used university students or staff as participants; one of the exceptions is Barsam and Simutis (1984) who used military personnel as participants. It remains to be proved whether the findings from research involving university or college participants will prove valid for military personnel.

Overall, the literature is contradictory concerning the effect of virtual environments on the acquisition of spatial knowledge. The studies accessed for this research cover a wide range of environments (real and virtual), and different methods of eliciting the acquisition of spatial knowledge.

In some studies, the use of a virtual environment was found to have a positive impact on the performance in spatial knowledge tests: Goldin and Thorndyke (1982) showed that for certain types of spatial knowledge, simulated exposure was more effective than navigation; Devlin and Bernstein (1995) observed that participants learning from text or maps made significantly more errors; Wilson et al (1997) showed evidence of transfer of information from the virtual to the real environment.

In other studies, the use of virtual environments was found either to have no effect or a negative effect: Richardson et al (1999) concluded that given equivalent exposure to the environments there was no effect; Goldin and Thorndyke (1982) also showed that for some measures of performance there was no differences between the tasks; Witmer and Sadowski (1998) showed that errors within the virtual environment were approximately double those in the real environment; Rossano and Moak (1998) showed no significant differences between learning from a real or virtual environment.

Accuracy in the recall and spatial tasks appears to be variable: Goldin and Thorndyke (1982) observed that the participants in their research did not perform well at the orientation tasks.
Spatial ability

Of the references examined to date, only two have explicitly assessed the impact of “sense of direction” on the metrics used to interpret spatial knowledge. The first is a paper by Kozlowski and Bryant (1977), who used self-assessment to determine sense of direction in a group of undergraduates. This assessed sense of direction was then correlated with performance measures in a familiar environment: those with good sense of direction performed better than those with a poor sense of direction. In a novel environment (a simple maze), those with a good sense of direction improved their accuracy in the performance measures, whereas those with a poor sense of direction showed no such improvement.

However, the maze used in these tests was a series of maintenance tunnels under the familiar buildings. These tunnels allowed no visual cues to assist in orientation, and therefore subjects were forced to rely on calculated or estimated measurements to perform the orientation metrics. This study provides some insight into the influence of sense of direction on the metrics performed in a familiar environment.

The second paper by Pearson and Ialongo (1986) describes a battery of spatial ability tests administered to a group of college undergraduates, followed by measures of environmental knowledge in an unfamiliar environment. The subjects learned the novel environment through a series of still photographs. The correlation between the spatial ability tests was higher than that between the tests and the environmental knowledge. A recommendation from this study is that future work should investigate the influence of general intelligence and past experience of way finding on environmental knowledge.

Prestopnik and Roskos-Ewoldsen (2000) studied wayfinding in relation to sense of direction, ability, familiarity and gender. Participants were psychology undergraduates. The research concluded that sex and sense of direction were the best predictors of wayfinding ability, but sense of direction predicted response latency and environment familiarity and gender predicting accuracy.
Barsam and Simutis (1984) showed that participants with high spatial ability performed better at terrain visualisation tasks. However, active exploration did not improve the performance of medium and low spatial ability.

The research by Barsam and Simutis (1984) is one of the few studies found that used military participants. This research aimed to investigate the utility of computer based graphics for terrain visualisation to overcome frequently reported difficulties in interpreting contours from paper based mapping. This research found that, intuitively, soldiers with high spatial ability scores performed better at terrain visualisation tasks, also that when these soldiers with high spatial ability scores were permitted to select the viewpoint on the computer graphics their performance at the task nearly doubled. However, active participation in the learning process did not affect significantly the scores of medium and low scoring spatial ability soldiers. The authors posit that this difference is due to the high ability soldiers actively choosing appropriate views and lower ability soldiers actively choosing less appropriate views for performing the task.

**Orientation specificity**

Various studies have suggested that learning new environments from maps leads to orientation specificity when this knowledge is tested in the real environment. In part this is due to the fact that most maps are presented with North direction upwards on the sheet. Therefore measurements of relative direction made when the subject is contra-aligned will be less accurate than those made when the subject is aligned.

Experience with subjects completing blank maps of a training area they have been exposed to shows that subjects will orient the blank map according to how they have perceived the original map when learning the environment. In this case, where subjects passively learning the environment around a “bird table”, some will see the map oriented N upwards and some will see it oriented N downwards.

This study has found little evidence to suggest that learning environments from VR is also subject to orientation specificity; however, it is possible that the
orientation may be sensitive to the direction of travel through the virtual environment, rather than sensitive to the compass direction.

Presson and Hazelrigg (1984) investigated the way in which environments are learned and the effect that these methods have on the orientation specificity observed. This study showed that the map learning group showed strong alignment effects, whereas the walk learning group did not. However, they posit that the differences observed are not due solely to the modalities involved in the learning process (i.e., visual or kinaesthetic); primary (defined as direct) or secondary (defined as symbolic) learning was found to be a factor in the alignment effect observed.

Roskos-Ewoldsen, McNamara, Shelton and Carr (1998) investigated orientation specificity in both large and small scale environments, using either a four point path or a display of objects. The results obtained did demonstrate orientation dependency, with little or no evidence of the effect of the size of the environment. This research contradicts the findings of Presson and Hazelrigg (1984).

**Scene components**

From the rural experiment, it was found that not all participants recognised images of the environment that they had walked through. This led to the question of how photographs or models of scenes from an environment were analysed and learned. A review of the literature revealed that some work has been undertaken in this area, but that many of the scenes studies were necessarily simple and objects within the scenes were simple and readily identifiable.

Christou and Bulthoff (1999) used a computer simulation of a real attic allowing participants to move around and become familiar with this environment. The origin of the participants was not described. The research aimed to determine whether participants could identify novel perspective viewpoints and topographic floor plans. Familiar viewpoints were the most easily recognised, although novel viewpoints were identified, although this generalisation decreased when participants passively learned the environment.
Mou and McNamara (2002) investigated frames of reference within spatial memory. They define spatial reference systems into two categories: Egocentric and Environmental; where egocentric frames specify location with respect to the observer and environmental frames specify location with respect to other objects. This research required participants to learn the location of a small number of objects located within a room. Participants were college students. The results obtained suggested that participants were using an environmental frame of reference.

Mandler and Johnson (1976) used stylised line drawings to investigate recognition of complex pictures. They used organised (i.e., realistic) and disorganised stimuli. Participants were undergraduates. They discovered that recognition of realistic or coherent images was not better than recognition of incoherent images, and that for some types of information recognition was better in the disorganised scene. Spatial location information was better recognised in organised scenes and spatial composition was better recognised in incoherent scenes.

Hock and Schmelzkopf (1980) studied the abstraction of schematic representation of scenes from photography, providing empirical evidence for the formation of schema in the integration of visual information. This research used real world images of an urban environment, and participants were asked to determine the location from which the images had been taken on images used in the learning process and new images. Participants, who were students, were shown to be able to abstract an overall schematic understanding of the environment from the partial images used for learning.

Marks, McFalss and Hopkinson (1992) investigated the effects of task demand on the encoding factors for scene contexts. This is defined as the increased probability of recalling items associated with yes responses better than those associated with no. For this research they used congruous and incongruous scenes for cued recall tasks. This research used undergraduates as participants. Interestingly this research did not identify any significant effect of response type or coding congruity for picture recognition, although the coding congruity does assist the recall of the picture identity.
Wang and Simons (1999) investigated the recognition of scenes and the dependence of this recognition on the viewpoint. Movement of either observer or object results in a new view of a scene, however recognition still occurs and there are two possible mechanisms for this: transformation rules to compensate for changes or encoding of particular features. There appears to be a difference in recognition when the objects move relative to a stationary observer or whether the observer moves. This paper investigates the issues in cases where the change was passive and where the viewer controlled the change. It was demonstrated that recall was worse for orientation changes than for viewpoint changes.

Mandler and Parker (1976) described the factors affecting memory for information in complex pictures. They aimed to study what people remember about complex pictures. The pictures used were either organised or unorganised in either indoor or outdoor scenes. Participants were students and were asked to recognise elements from the scene from a number of slightly varying alternatives, and secondly to reconstruct object locations. Organisation of the scene had a significant effect of memory for location of objects.

Metrics

Since the proposed experiments for this research will involve assessing the acquisition of knowledge from participants, it was considered important to review the literature for methods of assessing such acquisition.

Spatial ability

Some studies reviewed considered the impact of spatial ability on the performance of participants in these tasks. Juan-Espinose, Abad, Colom, Fernandez-Truchaud (2000) investigated the contribution of visuo-spatial ability on large scale space orientation, using either field or computerised tasks. They have developed a five factor hierarchical model, including three abilities representing \( g \) and the employment of visual and verbal components over spatial orientation and updating.

Allen, Kirasic and Dobson (1996) investigated the factors associated with spatial ability. Participants were predominantly students and were presented with
a battery of psychometric tests, experimental tasks and environmental learning. This resulted in a five factor model: a spatial ability factor, a spatial sequential memory, a spatial perspective latency and topological knowledge and Euclidean direction knowledge. This was confirmed in a second experimental setting.

Cutmore, Hine, Maberly, Longford and Hawgood (2000) investigated factors affecting the acquisition of knowledge from a virtual environment. The factors investigated were gender, active or passive navigation, cognitive style, display information and hemispheric activation. Both route and survey knowledge acquisitions were assessed. Participants were university students. No differences were observed between active and passive exploration, however the introduction of landmarks into the environment provided useful navigational clues. Males used the landmarks more efficiently than females. Participants with high visuospatial ability performed better at Euclidean distance estimation. The authors concluded that individual differences in spatial ability can result in different representations of the environment and that not all individuals may benefit equally from exposure to virtual environment information.

Environmental knowledge metrics

Most authors already quoted use the measures in some format to assess environmental knowledge; these measures comprised Bearing estimation from current location to landmark; Distance estimation – straight line between two landmarks Route description, from current position to landmark and Distance estimation – along route between current position and landmark.

Wilson et al (1997) showed that using a pointing test with landmarks out of sight of the participants was the most sensitive measure and that map drawing accuracy was similar to pointing accuracy.

Young (1999), and previously Lynch (1960), proposed a method of capturing participants’ spatial information through sketch maps. Lynch characterised the output of such maps to include landmarks, nodes (defined here as junctions of routes), districts (distinct areas) and features amongst other measures.
Many studies required participants to imagine themselves at a particular point within a learned environment, facing a particular direction and then recall the relative locations of landmarks from this imagined point. It is possible that this method could be applied to the research environments for this programme, but it would require careful elicitation of the imagined location to ensure that participants were remembering the correct elements of the environment. It is possible that this would not be appropriate in the rural location, as many of the locations look similar with only subtle differences. It would be difficult in this case to determine whether errors are occurring due to mis-remembering the imagined start location or poor learning of the relative locations of landmarks.

Fiore and Schooler (2002) investigated verbal overshadowing of spatial reasoning. Verbal overshadowing of a mental model occurs when verbalization causes over concentration on specific features rather than an holistic view. Their hypothesis that verbalization would have a negative effect on Euclidean estimation and a positive effect on route distance estimation was tested experimentally. Participants were college students. The results showed that verbalisation did have a negative impact on Euclidean distance estimation, but that there was no difference in route distance estimation.

**Proposed study areas**

Given the contradictory nature of the available research concerning the effect of virtual environments on the acquisition of spatial knowledge, it is concluded that there is no clear answer to the questions posed in the introduction. The question remains to be answered conclusively whether or not the use of GIS and imagery toolsets will improve the acquisition of spatial knowledge for a new environment.

With one exception, the available literature did not use military personnel as participants, and therefore there is a supplementary question to be answered: considering some of the training in orientation and map reading that military personnel can undertake, do military personnel differ in the acquisition of spatial knowledge (particularly considering much of the literature uses university or college students and staff as participants).
Many of the previous research studies have used urban environments as test situations; some have used sections of college campus or towns, others have used the interior of buildings. Some studies have used real environments and others fictitious. Few, if any, studies have used an exclusively rural environment to investigate spatial knowledge acquisition. This is an important omission for the purposes of this research, and therefore the inclusion of the rural environment is considered important in the context of the experiments to be conducted. However, the personnel considered to be the end users for this type of toolset are likely to require both urban and rural environmental knowledge, and therefore there is a requirement for this research to compare the effects of the toolset in both situations.

**Spatial knowledge**

For simplicity and the elicitation of factors affecting spatial learning, the provision of materials for learning in much of the research have been examples of mapping, simple virtual environments or direct experience. The toolset available to this research was a more complex system of mapping, aerial photography, panoramic imagery and simple three dimensional models.

The effect of background, experience and role on the acquisition of spatial knowledge is not covered within the available literature, and it is considered within the context of this research that this is an important omission. Therefore it is concluded that this research should as far as possible include an analysis of the impact of these factors on the overall outcome.
Chapter Three

SYSTEM DESCRIPTION

Overview

Sections

This short chapter describes the tools used for these experiments. The first section contains a description of the GIS (Axis™), subsequent sections describe the imagery (panoramic and three dimensional) used to illustrate the novel environments.

Tools

Overview

A number of options for using and displaying mapping and imagery information were used during this exercise. The principal components of the technologies available to the troops within the appropriate experimental conditions were GIS for displaying mapping and aerial photography; higher resolution still photography; lower resolution panoramic photography and simple 3-D models of particular buildings. These technologies are described in more detail in the following sections.

Geographic Information System (GIS)

The GIS used was AXIS2000™; this product allowed the display and manipulation of mapping and orthorectified aerial photography. An example of the photography display is shown at figure 3-1. The aerial photography available to the project was orthorectified vertical aerial photography. This was taken during summer 2000. Some limited up to date aerial photography was available offline, but had not been incorporated into the GIS (this was because the aerial photography had not been available for sufficient time to be orthorectified and incorporated).
The GIS allows the creation of overlays, which may be displayed if required. The overlays displayed at figure 3-1 show the location of hotlinks to further imagery products. These hotlinks are colour coded according to the type of product. The details of the types of imagery available are shown on the second, lower, toolbar in the Axis window. Double clicking on a hotlink will display the appropriate imagery in another window. The normal GIS functions of pan, zoom in and zoom out are available for both mapping and aerial photography. Zooming in or out on the map display will change the scale of the mapping as necessary. There is also a gazetteer available with all the locations, landmarks and relevant features available, this allows participants to easily locate items of interest and to centre the display accordingly.

Figure 3-2 shows the AXIS2000 window displaying only the 1:10,000 scale mapping plus the hotlink overlays.
Imagery

In addition to the orthorectified aerial photography, there were three types of additional imagery available: ground stills, aerial stills and panoramas. Some low-resolution, simple 3-D models had been created for particular buildings around the training area.

Figure 3-3 shows a ground level still photograph. These are accessed from the GIS by clicking on the appropriate hotlink, and are displayed in ER-Viewer™. ER-Viewer™ allows the user to move, zoom in and zoom out of the imagery using simple mouse controls.
Aerial stills photographs were taken around points of particular interest within the training area. As with the ground level imagery, these are accessed via the hotlinks and are displayed using ER-Viewer™. An example is shown in figure 3-4.
A Cyclovision™ lens together with a Nikon CoolPix 990 digital camera were used to take single shot panorama images around the training area. These images were processed using ParaShot Viewer software so that the 360° image could be displayed and rotated within Internet Explorer¹. Figure 3-5 shows a sample section of a panorama. The images are annotated with relevant information using Adobe Photoshop V5.5. Annotations on these images include landmark identification information, direction information and road names where these are available.

¹ A plugin (MGI Zoom Viewer) is required to display these images.
Simple 3-D models

Canoma™ version 1 was used to create simple 3-D models from aerial photographs, within a few hours. These models can be exported to a VRML 2 model that can be displayed within Internet Explorer, using a VRML viewer. The viewer shown in figure 3-6 and available to the participants in this research, is Cosmo Player™, but several versions are available.

Cosmo Player™ allows the user to rotate, zoom in or out and pan the image. This is a simple model, which assumes that the structure sits on a flat plane. As can be seen from the figure, the options for creating vegetation are limited. However, the model does allow the representation of simple buildings for presentation purposes. These models were included in the trials to assess the usability of low-resolution models.
Rural usage

Of the two groups with access to full GIS and imagery technologies, only one had access to full presentation facilities, as there was insufficient room at the base location for the second group to be able to use the specialist projectors available. Therefore, the material was presented to the second group prior to leaving each day, and first group had the material available for individual learning as required.
Chapter Four

EXPERIMENTAL OVERVIEW

Background

This section describes the three experiments undertaken for this research, and gives a description of the terms used for each experimental category.

Experiments conducted

A series of three experiments were conducted: firstly, a longitudinal study over a military exercise lasting 6 days in a rural environment; secondly, a short experimental phase where participants were brought to an urban environment for approximately 3 hours and finally, a short experimental phase where participants were shown a series of panoramic images for approximately 1 hour. The participants in each experiment were different and in some cases from different military specialisations and backgrounds.

Terminology and definitions

All participants in the rural and urban experiments were given time to use the available methods to learn the environment and plan a walk around a specified route within the environment. In both the rural and urban conditions two or three types of condition were evaluated: a control group (control) who had access only to paper mapping (the normal military condition); an imagery group (imagery) who were given access to the GIS, paper mapping and imagery (still and panoramic) for the environment and an imagery plus instruction (I+I) group who were give access to the GIS, paper mapping and imagery as for the second group, but were instructed to specifically examine the imagery and mapping for points where the group might be vulnerable during the walkthrough. This last condition was only examined in the urban environment.

Each participant in both environments was asked to provide estimated bearing to a nominated key point or landmark within the environment and
estimated distance to that key point (Euclidean or “as the crow flies” distance). Each participant was asked to complete or update a sketch map of the environment showing the features learned.

Sketch maps were analysed for content and the measures used were: the total number of identifiable landmarks (ie landmarks with either a label or a distinctive shape showing their identity), the number of nodes (defined here as junctions between roads and paths) and the number of features (defined here as distinct areas that are not a landmark, for example a car park could be represented as a bounded entity on the map with either a label or a picture of a car to identify it).

For experiment three, groups of military personnel were asked to identify features and landmarks from a series of panoramic images. The participants were randomly divided into two groups, those asked to identify prominent landmarks (“prominent” group) and those asked to identify particular points (“specific” group).

Prominent landmarks were defined as those features within the landscape that could be used as wayfinding points in the environment for directing others along specified routes, ie a feature sufficiently unambiguous that the location of the image is easily recognised.

Particular points are defined as those features that identify features that were distinctive and areas where the participants may have felt vulnerable.

**Presentation of the methods and results**

For clarity, each of the experiments is reported separately. Each of the following three chapters give details of the methods used, the participants taking part and the results obtained for each of the three experiments.
Chapter Five

EXPERIMENT ONE: RURAL ENVIRONMENT

Background

From the literature review, it can be seen that whilst there is evidence to suggest that participants can acquire route and survey knowledge from maps, the literature is less confirmatory concerning this acquisition from virtual environments. Real environments used in the literature have largely consisted of single buildings, campus or urban environments. The participants in much of the literature are college students or college staff. It is apparent that military participants may vary from college or university students and staff in academic training, specific orientation training and experience. Military activities can occur in both rural and urban environments, and therefore it was decided that investigation of the use of maps and imagery tools in the rural environment should be investigated using the participants who could potentially benefit from the use of such tools.

This experiment aimed to investigate the learning process, specifically how the participants built up knowledge and a cognitive model of a new environment. The aim was to assess the impact of the available technologies on that learning process.

There are potentially three methods of learning a new area and creating a mental model of that area: from mapping, from visualisation techniques and from direct experience. In general from Thorndyke and Hayes-Roth (1982) and others, the literature suggests that direct experience of the environment is the optimum method of learning, however in the normal military process an initial direct experience of the environment is not always possible. Where this direct experience is available, it may not be recent experience, and may be limited to selected personnel within the group.
The literature concerning the effects of virtual environments on learning actual real world information is unclear, with some authors claiming an effect and some (Wilson 1997) concluding that no effect is present.

There are several questions remaining from the literature to be answered, and in particular, to attempt to provide some confirmatory data on whether or not the use of a virtual environment does allow participants to transfer spatial knowledge to a real environment.

As discussed in the introduction, it is necessary for the military to work in both rural and urban environments, therefore this research should investigate the effects of virtual environments in both types of real environment.

Whilst planning this research, the opportunity to participate in a training programme was made available, this training programme was scheduled to last six days, and took place in the rural environment described below.

The environment used for this rural experiment is an isolated and enclosed rural training area. There are a few farm and other buildings, and the environment is well served with paths and roads. The area is relatively large, about 7km by 2km in approximate dimensions, which is larger than those environments used by previous studies. Within the overall area, there are prominent features such as distinctive hills, distinctive junctions and visible buildings. The area is bordered along one edge by the sea.

The nature of the training exercise included four groups of twelve individuals working on separate tasks during each day, such that each group completed each task. The physical infrastructure of the location allowed for two of these groups to have access to the imagery toolset (the imagery groups) and for two to work with conventional mapping (the control groups).

**Approach**

The approach used to investigate these questions was in part derived from the experimental approaches used in the literature, and in part dictated by the constraints imposed by the training programme underway. Many of the research studies identified in the literature compared maps, virtual environments and direct navigation in some combination. The methods used to elicit the acquisition
of spatial knowledge generally involved pointing tasks, Euclidean and route distance estimation, sketch maps and recall tasks. This experiment aimed to include the pointing tasks, Euclidean distance estimation and the sketch maps to identify the acquisition process for the spatial information about this rural environment. Using these methods would allow comparison with previous research, as well as being practicable within the experimental set up.

Methods

Participants

The participants for this experiment were 46 male military personnel. These were divided into two groups of twelve members and two groups of eleven members, these groups were members who normally worked together for the purposes of their training and were not assigned to groups for this experiment.

The participants ranged in age from 17 to 33. Their length of service in the military ranged from less than six months to fifteen years. Only eleven of the participants reported having worked within their teams before. Four participants reported experience of this particular rural environment prior to the experiment. Of these four, one had visited the area during the year of the experiment and two had visited more than three years previously.

Eight participants reported using computers during their work. Seven of these used personal computers daily. Twenty-six participants reported using personal computers at home, fourteen of these using personal computers daily and sixteen reported experience of using the Internet.

Participants were asked to grade their sense of direction on a five point scale, from Very poor to Very good. Table 5-1 shows the breakdown of these results.
Table 5-1: Sense of direction self assessment

<table>
<thead>
<tr>
<th>Grading</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Poor</td>
<td>1</td>
</tr>
<tr>
<td>Poor</td>
<td>1</td>
</tr>
<tr>
<td>Average</td>
<td>17</td>
</tr>
<tr>
<td>Good</td>
<td>20</td>
</tr>
<tr>
<td>Very good</td>
<td>7</td>
</tr>
</tbody>
</table>

The participants performed one of three roles during this experiment (which were their normal military roles): group leader, team leader or team member. Within the group of participants for this experiment, there were three group leaders, 12 team leaders and 31 team members.

Materials

Within the rural environment used for this experiment there were accommodation and working areas set up for each of the four groups of personnel undertaking the training and research. Of these four locations, for practical reasons, only two were suitable for setting up the imagery conditions (with sufficient space for computers, projectors etc). As each group of participants participating in the experiment lived at their base location as well as worked from this location, it was not practical to move them mid experiment and therefore a cross over design could not be implemented. Maintaining the same personnel in the same experimental groupings simplified the practical arrangements of allowing the experimental groups access to the necessary technology.

The control group had available to them: standard tools consisting of paper maps and printed aerial photography.

The imagery group had the standard tools plus the imagery toolset as described in section three. This included: a web browser set up with linked panoramic images, a GIS with both mapping and aerial photography and terrain model.
Experimental design

For these trials a simple non-equivalent control group design of imagery and control groups were established. This research took place using military personnel who were already undertaking a standard military training programme.

Procedure

Pre measurements

Prior to the start of the military exercise the participants were asked to complete a consent form and a questionnaire to provide background information (the full questionnaire is shown at Annex A), this information included: Age, Length of service, previous experience of the rural environment, IT skills, use of internet.

Experimental procedure

This experiment took place during a training period, lasting six days. On each day, each group of participants were required to undertake two distinct activities, separate to the experiment. On each activity, they were taken to a specified start point (which was not necessarily located on a road within the rural environment), they then walked on a pre-determined route through the rural area, for the purposes of their training. Each task lasted approximately three hours, and each group undertook two tasks each day. Therefore there were a total of 48 walks over twelve routes through the rural area, and each group undertook each of the twelve routes. Each group used the materials available (i.e. maps or GIS and imagery) to them for planning and preparing the routes prior to each daily activity (although not between activities on each day).

Although uncontrolled by this experiment, this training programme provided a good opportunity for undertaking the experimental procedure, and each group planned a stop during each task to be questioned for the in field measurements.
In field measurements

To capture the data in the field, the researcher was assisted by five scientists, so that field measurements were completed without unduly impacting on the military exercise.

The nature of the training programme demanded that each group should plan a walk around a specified route within the rural environment. Each group was required to plan the routes prior to the commencement of each day, using whichever tools had been assigned to them. Each walkthrough lasted between three and four hours.

The researchers met the groups at the same pre-planned location for each walkthrough task. The location was located on the route that the group had travelled and had studied during the planning activities.

The researcher took a GPS reading of the location of the measurement point, using commercial Garmin™ III GPS, (the GPS setup was checked for accuracy before going out on the exercise, it was set up for OSGB and datum was also OSGB).

The researcher recorded the direction of travel at the point of measurement, and the information given by the participant. Direction of travel and direction to key point was measured as bearings by commercial hand held compass. The location of the measurement points and key points were recorded as 8 figure grid references using Garmin III commercial hand held GPS.

All teams within a group were brought to the same position and all measurements were taken from each participant at this point.

A list of 15 key points around the range was established. From this list, a sublist of 8 key points was selected for each test session. The key points were checked to ensure that they were not closely located to the point used to meet the group, and that they were not immediately visible to any of the participants at the time of measurement.

Each participant was asked to locate two key points, as far as possible, participants following each other were asked to locate different key points, to
ensure that there was no copying of information between the individuals. From
the direction that the participant was facing, each participant was asked to point
to the key point. The researcher recorded this bearing using a hand held
commercial compass.

If the participant did not know where the key point was, then this was
recorded as unknown. The participant was asked to complete the information for
the second key point. If this point was also unknown, then this was recorded,
and the test for that individual was complete. The participant was not asked for
any further key points at this stage.

During these tests the researchers were asked to collect the following data
from each participant: Direct distance ("as the crow flies") to each key point, A
route to each key point and Landmarks on each route to that each point

These points were recorded using pre-prepared forms at the scene. The
routes were used to check that the participant was referring to the correct
location as the key point.

Post activity measurements

Each member of the group was asked to undertake post task testing
according to the schedule at table 5-2.
<table>
<thead>
<tr>
<th>Day of experiment</th>
<th>Tests to be conducted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>Spatial knowledge tests</td>
</tr>
<tr>
<td>Day 2</td>
<td>Spatial knowledge tests</td>
</tr>
<tr>
<td></td>
<td>Blank maps (update)</td>
</tr>
<tr>
<td>Day 3</td>
<td>Spatial knowledge tests</td>
</tr>
<tr>
<td>Day 4</td>
<td>Spatial knowledge tests</td>
</tr>
<tr>
<td></td>
<td>Blank maps (update)</td>
</tr>
<tr>
<td>Day 5</td>
<td>Spatial knowledge tests</td>
</tr>
<tr>
<td></td>
<td>Blank maps (Update)</td>
</tr>
<tr>
<td>Day six</td>
<td>Spatial knowledge tests</td>
</tr>
</tbody>
</table>

*Blank (or sketch) maps test*

On alternate evenings the participants were asked to complete or update blank maps. On the second evening, the participants were given a sheet containing only an outline of the training area. The participants completed the blank maps in pencil. They were asked to add as much detail as possible including roads and tracks, significant landmarks (e.g. quarries, streams, junctions etc), key points, i.e. significant locations pointed out to them in the introduction.

On completion of the blank map, the participant wrote name, and other identifying information (e.g. group) on the reverse of the blank map for identification purposes. The researcher made a copy of the completed map (whether there were any features entered or not) and the copy was labelled with the date and time that the test was completed.

Each subsequent evening when the participants were requested to complete blank maps, the participants updated their original map. The participants were asked to make whatever changes were necessary to the map...
so that it represented the best of their knowledge at that time. Features could be added, moved or removed during these sessions.

On completion of the blank maps on these subsequent evenings, the researcher made further copies of the maps which were labelled with the time and date of the test.

*Spatial knowledge tests using photography*

Pilot trials had shown that the tests during the walking tasks were unpopular with the participants, and so it was decided to test alternative measurement strategies. The most practical option considered was to use imagery. Each evening, once all walking tasks had been completed, participants from two of the participating groups were shown 360° panoramas.

There were 17 panoramic images available for testing. These images had no annotation to aid recognition. Thirteen of these images showed junctions, either t-junctions or crossroads. The images for presentation to each participant were chosen to reflect the activities that that group had undertaken on that day, and so successive participants did not all see exactly the same images.

The panoramic images were taken from the briefing material, but with all annotations removed, so that there were no cues other than the landscape and landmarks. The plain photos were shown on a laptop so that the participant could orient himself or herself. From a laminated printout of the photo and a map, the participant was asked to provide the following: the location that the photo was taken, the direction of north (which was marked on laminate with wipeable pen), the identity of the key points marked on the map, the location of 2 key points from the point at which the photo was taken (again the directions to be marked on the laminate using a wipeable pen), the straight line distance from the location of the photograph to the key points, a route from the location of the photograph to the key points.

If the participant did not know the location of the photograph, and was unable to recognise any of the features on the photograph, then this was recorded as not known and the next photograph was shown or the test was complete.
Each participant was asked to provide information from two photographs. Care was taken to ensure that the same photographs were not used for successive participants, so that the effect of a participant remembering previous answers was reduced.

**Analysis**

**Spatial knowledge measurements**

The spatial knowledge test results were recorded as a relative bearing and a distance in metres. The location of the test site was recorded as an eight figure grid reference. A true bearing and distance was calculated from the test location to the grid reference of the key point.

The difference between the estimated bearings and distances and the true bearings and distances were calculated by simple subtraction to create an error measure for both distance and bearing. The distance errors were calculated as a percentage of the true distance. The bearing errors were calculated as a percentage of the maximum bearing error possible (i.e. 180°). These errors were averaged over the tests for each day for further analysis.

**Map measurements**

For the rural trials, each participant was asked to complete or update a sketch map based on an outline of the test environment. A template\(^2\) was produced, which allowed the simple reckoning of the estimated grid reference of the landmarks and features recorded. The grid reference of the estimated landmark position was compared to the actual grid references, and simple subtraction gave a distance and bearing error for each landmark. The number of landmarks, nodes, features and districts were counted and entered as simple integers.

The aim of this analysis was to assess the accuracy of the participant’s positioning of landmarks. A landmark on the sketch maps was defined as a

\(^2\) As each blank map test was created on a standard sheet with the outline of the environment already in place, a template of the appropriate grid reference squares was produced to facilitate measurement of the key points.
building, specific delineated area with dimensions (for example a gateway or fire
muster point) or a specific named road junction. To be included in the analysis,
the landmark had to be identified by a symbol and a name on the sketch map,
the only exceptions to this were buildings of such specific shape that they were
identifiable (for example the only E shaped building on the site).

The actual distances and bearings between all the possible pairs of
landmarks were calculated using grid references from the GIS. Simple subtraction
was used to calculate the differences in bearing and distance.

Results from the rural experiments

In all graphs for this section, where error bars are shown they are defined
as ± 95% Confidence Level of the mean, unless otherwise stated.

Data descriptions and missing data

The experiments ran daily over a six day period, so for 46 participants
there should be a total of two measurements per test location, and two test
locations per day, a total of 1104 data points would be expected. However, there
were occasions where individual participants were absent from tests. On day five,
perticularly inclement weather prevented many of the second test session
(afternoon) measurements taking place.

Table 5-3 shows a summary of the data points collected:
### Table 5-3: Data points collected

<table>
<thead>
<tr>
<th>Day</th>
<th>Spatial Tests</th>
<th>Sketch map tests</th>
<th>Imagery spatial tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>Average distance error (2 test locations)</td>
<td>Not Tested</td>
<td>Not tested</td>
</tr>
<tr>
<td>Day 1</td>
<td>Average bearing error (2 test locations)</td>
<td>Not tested</td>
<td>Not tested</td>
</tr>
<tr>
<td>Day 2</td>
<td>Average distance error (2 test locations)</td>
<td>Blank map features</td>
<td>No of landmarks recognised</td>
</tr>
<tr>
<td>Day 2</td>
<td>Average bearing error (2 test locations)</td>
<td>Blank map average distance error</td>
<td>Not tested</td>
</tr>
<tr>
<td>Day 2</td>
<td>Not tested</td>
<td>Blank map average bearing error</td>
<td>Not tested</td>
</tr>
<tr>
<td>Day 2</td>
<td>Average distance error (2 test locations)</td>
<td>Blank map features</td>
<td>No of landmarks recognised</td>
</tr>
<tr>
<td>Day 2</td>
<td>Average bearing error (2 test locations)</td>
<td>Blank map average distance error</td>
<td>Not tested</td>
</tr>
<tr>
<td>Day 2</td>
<td>Not tested</td>
<td>Blank map average bearing error</td>
<td>Not tested</td>
</tr>
<tr>
<td>Day 3</td>
<td>Average distance error (2 test locations)</td>
<td>Not tested</td>
<td>Not tested</td>
</tr>
<tr>
<td>Day 3</td>
<td>Average bearing error (2 test locations)</td>
<td>Not tested</td>
<td>Not tested</td>
</tr>
<tr>
<td>Day 4</td>
<td>Average distance error (2 test locations)</td>
<td>Blank map features</td>
<td>No of landmarks recognised</td>
</tr>
<tr>
<td>Day 4</td>
<td>Average bearing error (2 test locations)</td>
<td>Blank map average distance error</td>
<td>Not tested</td>
</tr>
<tr>
<td>------</td>
<td>----------------------------------------</td>
<td>---------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Day 4</td>
<td>Not tested</td>
<td>Blank map average bearing error</td>
<td>Not tested</td>
</tr>
<tr>
<td>Day 5</td>
<td>Average distance error (2 test locations)</td>
<td>Blank map features</td>
<td>Not tested</td>
</tr>
<tr>
<td>Day 5</td>
<td>Average bearing error (2 test locations)</td>
<td>Blank map average distance error</td>
<td>Not tested</td>
</tr>
<tr>
<td>Day 5</td>
<td></td>
<td>Blank map average bearing error</td>
<td>Not tested</td>
</tr>
<tr>
<td>Day six</td>
<td>Average distance error (2 test locations)</td>
<td>Not tested</td>
<td>No of landmarks recognised</td>
</tr>
<tr>
<td>Day six</td>
<td>Average bearing error (2 test locations)</td>
<td>Not tested</td>
<td>Not tested</td>
</tr>
</tbody>
</table>

**Spatial tests – self assessed knowledge**

These self assessed knowledge scores were coded (with a score of 1 for "very good" knowledge and a score of 5 for "very poor" knowledge). A one-way ANOVA was conducted using experimental condition as a factor with the knowledge scores as the dependent variables; this showed no effect of experimental condition on the self assessed knowledge of the environment. A mixed two-way ANOVA on group (imagery or control), by days (day 1, day 4, day 5 and day 6) was conducted (days 2 and 3 were excluded since many of the participants failed to provide a knowledge score for these days, and inclusion of these days reduced the number of valid lines for analysis to 3. N on the 4 days included was 15 imagery and 11 control). This showed a significant effect of time ($F=7.38 (1.87, 44.90)$, $p<0.01$) and of the interaction between time and
experimental condition ($F=3.88 \ (1.87, 44.90), p<0.05$). The effect of condition alone was not found to be significant. Figure 5-1 shows the results graphically.

![Figure 5-1: The variation of the self assessed knowledge of the environment for the control and imagery groups, with a score of 1 for very good knowledge and a score of 5 for very poor knowledge](image)

On day one, the imagery group report poorer knowledge of the environment than the control group, although this difference is not significant. On subsequent days, the imagery group tend to report better knowledge of the environment than their control counterparts. There is relatively little change in the reported knowledge over the days for the control group, however the imagery group report better knowledge on day six than day one and this difference is significant.

**Spatial tests – Key point recognition**

Knowledge of the environment can also be assessed by whether the participants recognise the key points during each of the spatial tests. The key points selected for each day are shown in detail at Annex B. On some occasions
over the six days, personnel were absent from the experiment for personal
reasons (for example medical appointments). These personnel did not withdraw
from the experiment, but were not present to be tested on all the occasions,
these are shown in the table at Annex B as not tested. At the first test of the
day, and on some occasions the first test of the second series, each participant
was asked to assess their knowledge of the environment. The tables in the annex
show the assessed knowledge by category for each day.

The number of key points recognised by each participant was averaged for
each day of the experiment, and these scores recorded as a percentage as the
key point recognition. A two way ANOVA using experimental group (imagery and
control) by the six daily recognition rates as the dependent variables. The test of
within subject effects showed a significant effect of time ($F=11.52 \ (5,215)$
$p<0.01$), but no effect of the interaction between time and experimental
condition. There was an effect of experimental condition ($F=5.80 \ (1,43) \ p<0.05$).
These results are summarised in figure 5-2.

![Mean key point recognition](image)

**Figure 5-2**: Mean Recognition of the key points as a percentage of the number
of presentations

From figure 5-2 it can be seen that the imagery group overall have a higher
rate of recognition than the control group, and that there is an increase in
recognition rate across the sessions from day 1 to day 5. There appears to be slight trend towards a decrease in recognition rate on day 6, using a paired samples t-test across both experimental groups, this difference is significant ($t=2.17$ (1,36) $P<0.05$).

**Spatial tests – measurements**

The next section refers to the tests conducted during the activities undertaken by the participants, where each participant was asked to provide estimated range and bearing information to each of two key points.

Mixed two-way ANOVAs using experimental group (imagery or control) and each of the measured variables over the six days were conducted

*Distance Error*

No significant effects of experimental condition or time were observed on the mean error in estimated distance to key points.

*Bearing Errors*

A mixed two way ANOVA on group (imagery or control) by day (day 1 to day 6) was conducted. Significant effects of the interaction between time and experimental condition were observed in the mean error of estimated bearing ($F=2.80$ (5,180) $p<0.05$), The effect of experimental condition alone was significant ($F=5.30$ (1,36), $p<0.05$). These results are shown graphically in figure 5-3.
From figure 5-3 the imagery group produce smaller errors in mean estimated bearing to key points than the control groups.

**Sketch map tests**

A two-way mixed ANOVA on group by days was conducted on each of the variables measured from the sketch maps.

**Number of Landmarks**

A repeated measures analysis of the number of landmarks created on the sketch maps across the days of the tests (three days in total); Mauchly's test showed that corrections should be applied to the $F$ statistic for this analysis. The analysis showed a significant effect of time on the number of landmarks created ($F=68.59$ (1.422, 65.55), $p<0.01$) using the Greenhouse-Geisser correction. A significant effect of the interaction between experimental condition and time was observed ($F=6.07$ (1.422, 65.55), $p<0.01$) using the Greenhouse-Geisser correction. These results are summarised graphically in figure 5-4.
From figure 5-4, it is apparent that the number of landmarks created by the participants increases through the experiment, and that the difference between the imagery and control groups increased across sessions. One-way ANOVAs on the number of landmarks for each day of the test using experimental condition (imagery or control) as the factor showed the difference between the groups to be significant on day 5 ($F=5.83 \ (1,44) \ p<0.05$).

Bearing Errors

A mixed two way ANOVA on group (imagery or control) by time (days two, four and five) on the bearing error in the location of landmarks on the sketch maps was conducted; Mauchly's test showed that corrections should be applied to the F statistics. A significant effect of time was observed ($F=4.02 \ (1.514,66.612) \ p<0.05$ using the Greenhouse-Geisser correction), and a significant effect of the interaction between time and experimental condition was observed in the mean bearing error in location of the landmarks on the sketch maps ($F=4.694 \ (1.514,66.612) \ p<0.05$ using the Greenhouse-Geisser correction). The effect of experimental condition was not shown to be significant.
These results are shown graphically in figure 5-5.

Figure 5-5: Bearing error in location of the landmarks on the sketch maps by day and experimental group

From figure 5-5 the performance of the control group did not change with time significantly, however the imagery group appeared to deteriorate over the course of the experiment.

One-way ANOVAs on the bearing errors in landmark location on the sketch maps using experimental condition as a factor showed these differences between the groups to be significant only on day two ($F=6.960$ (1,44), $p<0.05$).

**Distance Errors**

A mixed two-way ANOVA on group (imagery or control) by the distance error in landmark location on each day of the test (day 2, 4 and 5) was conducted. A significant effect of time was observed in the mean distance error in location of the landmarks on the sketch maps ($F=3.771$ (1.521,66.923) $p<0.05$ using the Greenhouse-Geisser correction). These results are shown graphically in figure 5-6.
One way ANOVAs using experimental condition as the factor showed no significant differences between the groups.

**Other factors**

Mixed two-way ANOVAs were conducted on each of the variables already described to elicit any effects of self reported sense of direction or previous visits to the test location. All analyses showed no significant effect of either sense of direction or previous visits on these variables.

A mixed three way ANOVA on experimental condition (imagery or control) by participant role (group leader, team leader or team member) by the distance error in location of landmarks on the sketch maps was conducted. This analysis showed a significant effect of the interaction between time and role ($F=3.32$ ($3.20,64.02$), $p<0.05$ using Greenhouse-Geisser corrections). For this analysis Mauchly’s test of sphericity was significant therefore corrections were applied. This analysis is summarised graphically in figure 5-7. For all other within subjects variables tested there were no significant effects of role.
The group leader roles show particularly large errors in part due to the small number of participants in this role (two in each experimental group).

**Principal Components Analysis**

Principal components analysis was conducted on the dataset using all the variables described in the previous sections. Direct oblimin rotation was used, and a simple Eigen Values greater than 1.0 was used to extract the factors. The factors are shown in table 5-4.
Table 5-4: Principal Components Analysis pattern matrix for the rural data set

<table>
<thead>
<tr>
<th>Pattern Matrix$^a$</th>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 2 Map No landmarks</td>
<td>1.838E-02</td>
<td>.113</td>
<td>.694</td>
<td>2.401E-02</td>
<td>-.196</td>
<td>.248</td>
<td></td>
</tr>
<tr>
<td>Day 4 Map No landmarks</td>
<td>4.689E-02</td>
<td>2.812E-04</td>
<td>.985</td>
<td>6.320E-02</td>
<td>.105</td>
<td>1.288E-02</td>
<td></td>
</tr>
<tr>
<td>Day 5 Map No landmarks</td>
<td>-3.34E-02</td>
<td>-1.28E-02</td>
<td>.769</td>
<td>-3.28E-02</td>
<td>.208</td>
<td>-.252</td>
<td></td>
</tr>
<tr>
<td>Day 1 Average Bearing error</td>
<td>.215</td>
<td>-9.50E-02</td>
<td>-2.88E-02</td>
<td>8.340E-02</td>
<td>-.222</td>
<td>.673</td>
<td></td>
</tr>
<tr>
<td>Day 2 Average Bearing error</td>
<td>.197</td>
<td>.507</td>
<td>-.131</td>
<td>.124</td>
<td>.260</td>
<td>.192</td>
<td></td>
</tr>
<tr>
<td>Day 3 Average Bearing error</td>
<td>2.730E-02</td>
<td>8.370E-02</td>
<td>-.261</td>
<td>.354</td>
<td>.215</td>
<td>.458</td>
<td></td>
</tr>
<tr>
<td>Day 4 Average Bearing error</td>
<td>-1.34E-02</td>
<td>.460</td>
<td>-1.72E-02</td>
<td>-.134</td>
<td>.337</td>
<td>.387</td>
<td></td>
</tr>
<tr>
<td>Day 5 Average Bearing error</td>
<td>-9.23E-02</td>
<td>-2.09E-02</td>
<td>7.217E-02</td>
<td>-4.49E-02</td>
<td>2.473E-02</td>
<td>.839</td>
<td></td>
</tr>
<tr>
<td>Day 6 Average Bearing error</td>
<td>-.171</td>
<td>.336</td>
<td>-.186</td>
<td>1.208E-02</td>
<td>.187</td>
<td>.664</td>
<td></td>
</tr>
<tr>
<td>Day 1 Average Distance error</td>
<td>.847</td>
<td>5.853E-02</td>
<td>7.436E-02</td>
<td>6.831E-03</td>
<td>-.229</td>
<td>-4.13E-02</td>
<td></td>
</tr>
<tr>
<td>Day 2 Average Distance error</td>
<td>.907</td>
<td>-6.53E-03</td>
<td>7.688E-02</td>
<td>-3.31E-02</td>
<td>.200</td>
<td>.165</td>
<td></td>
</tr>
<tr>
<td>Day 3 Average Distance error</td>
<td>.633</td>
<td>-.138</td>
<td>2.507E-02</td>
<td>.586</td>
<td>.339</td>
<td>-.131</td>
<td></td>
</tr>
<tr>
<td>Day 4 Average Distance error</td>
<td>.523</td>
<td>-.197</td>
<td>-.175</td>
<td>-1.79E-02</td>
<td>-.380</td>
<td>.300</td>
<td></td>
</tr>
<tr>
<td>Day 5 Average Distance error</td>
<td>.939</td>
<td>2.645E-02</td>
<td>-3.32E-02</td>
<td>-2.58E-02</td>
<td>-1.88E-02</td>
<td>-4.78E-02</td>
<td></td>
</tr>
<tr>
<td>Day 6 Average Distance error</td>
<td>.844</td>
<td>.234</td>
<td>-4.99E-02</td>
<td>-.159</td>
<td>2.839E-02</td>
<td>-.131</td>
<td></td>
</tr>
<tr>
<td>Day 2 Map Average dist error</td>
<td>.113</td>
<td>.901</td>
<td>7.765E-02</td>
<td>-6.82E-02</td>
<td>-.116</td>
<td>-.163</td>
<td></td>
</tr>
<tr>
<td>Day 4 Map Average dist error</td>
<td>-3.26E-02</td>
<td>.961</td>
<td>4.613E-02</td>
<td>-6.75E-02</td>
<td>-.157</td>
<td>-1.49E-02</td>
<td></td>
</tr>
<tr>
<td>Day 5 Map Average dist error</td>
<td>2.056E-02</td>
<td>.905</td>
<td>7.715E-02</td>
<td>.128</td>
<td>-6.66E-02</td>
<td>4.257E-02</td>
<td></td>
</tr>
<tr>
<td>Day 2 Map Average bear error</td>
<td>-7.29E-02</td>
<td>-3.16E-02</td>
<td>9.961E-02</td>
<td>.925</td>
<td>-9.61E-02</td>
<td>6.560E-02</td>
<td></td>
</tr>
<tr>
<td>Day 4 Map Average bear error</td>
<td>-.141</td>
<td>8.226E-02</td>
<td>-3.21E-02</td>
<td>.926</td>
<td>-.146</td>
<td>-5.04E-02</td>
<td></td>
</tr>
<tr>
<td>Day 5 Map Average bear error</td>
<td>1.603E-02</td>
<td>.298</td>
<td>2.080E-03</td>
<td>.283</td>
<td>-.820</td>
<td>-5.99E-04</td>
<td></td>
</tr>
</tbody>
</table>

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
$^a$ Rotation converged in 12 iterations.

Table 5-4 shows the six factors elicited from the principal components analysis. Variables loading onto factor 1 are distance errors on all six days.

Variables loading onto factor 2 are: average bearing error on day 2, day 4, the distance errors in sketch map landmark location on all three test sessions.
Variables loading onto factor 3 are: the number of landmarks on the sketch maps on all three test sessions.

Variables loading onto factor 4 are the distance error on day 3, the bearing error in sketch map landmark location on days 2 and 4.

The variable loading onto factor 5 is the day 5 average bearing error in sketch map landmark location.

Variables loading onto factor 6 are the day 1, day 3, day 5 and day 6 average bearing errors.

A one-way ANOVA on the regression factors elicited from the principal components analysis by experimental condition (imagery or control) was conducted. There was a significant effect of condition on factor 4 ($F=6.40 (1,37), p<0.05$) and factor 6 ($F=10.04 (1,37), p<0.01$).

One-way ANOVAs on the regression factors elicited from the principal components analysis showed no significant effects of participant role, previous visits or sense of direction.

Post walkthrough tests

On Days 1 to 5 participants from two groups (one control and one imagery) were asked to provide spatial information from panoramic photographs (less annotations) presented to them. The aim of these tests was to investigate the possibility of using test images instead of spatial tests on the training area; the latter can be disruptive to patrols and soldiers resent being interrupted to complete them.

Table B-2 at Annex B shows the usage of the images over the test sessions. Images were selected for presentation based on the areas that the group had patrolled over during that day. A selection of five photographs was available and the test administrator could choose randomly between these that were presented to the participants. Each participant was presented with two panoramic images.

The participants were asked to identify the location at which the photograph had been taken; they were then given a map and asked to provide a
grid reference. Table 5-5 shows the number of instances of photographs presented for which the participant recognised the image, and those for which a grid reference could be provided. A measure of the accuracy of the grid reference is shown in the table as an average distance error in kilometres.

Table 5-5: Recognition of test photos out of a total of 22 presented each day

<table>
<thead>
<tr>
<th>Task</th>
<th>Group</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recognised name of location and give grid</td>
<td>Control</td>
<td>5</td>
<td>9</td>
<td>3</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Imagery</td>
<td>10</td>
<td>9</td>
<td>6</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Recognised name of location only</td>
<td>Control</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Imagery</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>The key point was not recognised by the participant</td>
<td>Control</td>
<td>16</td>
<td>10</td>
<td>19</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Imagery</td>
<td>8</td>
<td>8</td>
<td>13</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>The participant was unavailable for this test.</td>
<td>Control</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Imagery</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Average distance error of the grid reference (km)</td>
<td>Control</td>
<td>0.8</td>
<td>1.0</td>
<td>1.3</td>
<td>1.2</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Imagery</td>
<td>2.3</td>
<td>2.6</td>
<td>0.1</td>
<td>2.1</td>
<td>0.6</td>
</tr>
</tbody>
</table>

A mixed two-way ANOVA using experimental condition (Imagery or control) by the average recognition rate of the presented images on each day of the test was conducted. No significant effects of time or experimental condition were revealed. One-way ANOVAs on each of the daily recognition rate (i.e. the number of images recognised as a percentage of images presented on each day) by experimental condition was conducted. No significant effects were revealed.
It would appear that, in addition to those images where a grid reference could be given, the experimental group was able to name more locations than the control group, although repeated measures analysis and one-way ANOVAs did not show this effect to be significant. The mean daily recognition rate is summarised in figure 5-8.

![Recognition of photo tests](image)

*Figure 5-8: Recognition of the panoramic photographs in the post activity tests*

Overall, recognition rate of the imagery is low, but there appears to be a slight although non-significant trend towards the imagery group recognising more images than the control.

**Analysis of photographs used in the tests**

The photographs used in these tests were analysed to define their content. The results of this analysis are shown in annex B.

Few of the participants were able to complete the spatial tests for the photographs, and data were obtained sporadically, it was therefore considered that further analysis of this data would not be undertaken.
Discussion

Summary of results

The participants self reported knowledge of the environment significantly improved over the course of the experiment, and there was a significant interaction between experimental grouping and time. The participants exposed to imagery and GIS improved their knowledge of the environment to a greater extent than the control group.

The recognition of the key points used as stimuli in the spatial tests improved over the course of the six days of the experiment: there was a significant effect of learning, and a significant effect of experimental condition, but the interaction between time and condition was not significant. Overall, the imagery group recognised more key points than the control group.

Within the variables measured during the spatial tests, only the error in estimated bearing showed a significant effect of the interaction between time and experimental condition. Overall, the errors from the imagery group were smaller than those of the control group, and in both groups there is a trend towards decreasing the error over time.

Each participant was asked to create or update a sketch map of the environment on days two, four and five. A significant effect of both time and experimental condition was observed in the number of landmarks produced: the imagery group identified significantly more landmarks on each of the days than the control group, and in both groups the number of landmarks created increased over the course of the experiment.

The errors in location of these landmarks was recorded as errors in distance and bearing from the true location. These errors were relatively large, although the imagery group produced smaller errors than the control group, however the error produced by the imagery group appeared to increase with time. The imagery group distance errors in location of landmarks decreased with time. There was little apparent change in the distance errors of the control group over time. The imagery group appear to produce larger distance errors than the control group.
A significant effect of the interaction between time and role was observed for the distance error in landmark location on the sketch maps. No other factor (previous visits or sense of direction) were observed to effect the results.

Principal components analysis elicited six factors. Using these regression factors, significant effects of experimental condition were observed on two of the factors.

Two of the four groups undertook spatial tests using imagery after the walk through the environment. However, the rate of recognition of the images was low (less than 50% in all cases) and further analysis of these results was not undertaken.

**Learning the new environment**

The participants were asked to provide information concerning key points during the spatial tests, and there is a trend to show increased recognition of these key points over the course of the experiment. This is to be expected, since the list of key points used was relatively small, and therefore participants could be asked to identify the same point on a number of tests. In addition, the participants were walking over a number of routes through the environment (approximately 15km per day on each of six days), and so, from Thorndyke and Hayes-Roth (1982) and others, would be expected to acquire knowledge through direct experience. However, this direct experience would be expected to lead to route knowledge, rather than survey knowledge.

Route knowledge is defined as the ability to determine spatial relationships between landmarks and points within an overall route or path; survey knowledge is defined as the "bird's eye" view of the environment, and allows judgement of spatial relationships between landmarks, routes and points.

Evidence from the sketch maps shows that the participants were acquiring survey knowledge, and that the imagery group were more familiar with the landmarks in the area than the control group (although no more accurate in placing the landmarks on a sketch map).

Some key points were recognised easily by both groups, and a high percentage recognition can be observed, for example, by day three key points 1,
5, 6 and 7 are showing greater than 80% recognition. There is some evidence from these graphs to suggest that some key points are recognised more frequently by the imagery participants than the control participants: for example, key points 3 and 4 show greater percentage recognition rates by the imagery participants than by the control participants. However, it is not possible from the data captured in this experiment to demonstrate reliably that this is an effect of the presentation of the information and is not due to a confounding factor such as the routes undertaken through the environment by the participants.

From the spatial tests conducted on the rural area: it would appear that the imagery groups were able to provide information about more key points than the control groups. There were significant differences in the accuracy of the bearings recorded between the groups on day one, day three and day five. Significant effects of the interaction between learning (ie time across the days of the experiment) and experimental condition were observed in the errors in estimated bearing.

From the literature review in chapter two, it can be seen that there is considerable discussion of the acquisition process and merits of route and survey knowledge of an environment. From the results presented here, there is evidence of acquisition of survey knowledge of the environment, from the number of landmarks, features and nodes created on the sketch maps.

The blank map tests were used in these trials to assess the mental model created by the subjects. It would appear that there is a trend to suggest that the experimental groups were able to create more landmarks on their sketch maps but they could locate these at no greater accuracy in terms of relative location to the boundaries or other landmarks than their control counterparts. This finding would suggest that the experimental groups are learning more information about their environment. However, these results could arise from a number of causes: it is likely that the experimental group were highly motivated to interact with the experimental technologies. This motivation would not necessarily be present in the control groups. It is not known whether there was any revision of the environment prior to undertaking the maps test, if so, this again would influence the results.
As evidenced by the ability to recognise the names of landmarks, and to place landmarks on a sketch map, it is apparent that these participants were acquiring some level of spatial knowledge about the environment. However, the performance measures of pointing and the accuracy of the sketch map landmark location do not indicate that a high level of either route or survey knowledge was being acquired.

Observation of the participants during the learning phases prior to the experiment and during the experimental days highlighted an important difference between the groups: in one case the group actively participated in the use of the imagery tools, the second imagery group used a single participant to demonstrate the imagery whilst the remainder of the group watched passively. In general the control groups relied on a central demonstration using the maps available, and therefore the learning was passive. The difference between the imagery groups in this respect is an artefact of the experimental facilities, in that one group had a separate lecture room, whilst the second (passive) imagery group had only a single room for living and learning activities. This meant that the second group could not leave the imagery toolset running at all times, and therefore it was used for specific planning and demonstration purposes only. However, excluding the passive learning imagery group from the analysis does not identify significant differences between the groups. Analysis of the differences by groups (ie separating out those groups with active and passive learning) showed some significant differences between the groups; however this cannot at this point be confirmed whether this is entirely due to the difference in learning style, or whether this is in part a difference in leadership style between the group leaders.

There was no identifiable effect of role in these results, which would partially confirm the findings of Kinnear and Wood (1987) who showed that formal geography training had no effect on performance.

The previous literature studied did not undertake principal components analysis of the data collected, and therefore it is not possible to confirm the nature of the factors elicited from these data with previous findings. However, one-way ANOVAs conducted on the factors using experimental condition did
reveal that there was a significant effect of condition on two of the factors: factor 6 (bearing error on some of the days) and factor 4 (bearing error in landmark location for the sketch maps).

In summary, use of the imagery toolset did appear to aid learning about the rural environment; in particular initial errors in estimated bearing to key points was reduced in the imagery group, and the imagery group identified significantly more landmarks on sketch maps than the control group.

**Metrics**

Although a useful and sensitive tool for understanding the mental models of the environment that the subjects create, the blank maps test is unpopular and motivation to complete the test is lacking.

There would appear to be some questions concerning the recognition of imagery from a rural environment. It was apparent that a proportion of the subjects did not recognise the imagery used in these tests. In some cases, this effect was apparent even with images taken at points where the entire group had stopped (either at a point of departure for the walking tour or at a point where the participants were stopped on the route to answer questions). This lack of recognition was quite definite and participants were positive that they had not visited some locations shown in these tests.

This calls into question either the fidelity of the imagery used or the type of environment photographed. Some of the imagery was 18 months old, and of relatively poor quality. However anecdotal evidence suggests that where there have not been major changes in the environment of the photograph, these are equally likely to be recognised as newer, higher resolution images (further analysis of the data is required to finalise these conclusions).

Therefore, some questions remain concerning the nature of the environment to be photographed. Some limited analysis has been undertaken here to investigate the features within the image that aid recognition, but further work is required in this area. The reverse case should also be tested: ie does training with the imagery lead to recognition of the actual environment?
With a rural area, it is likely that images will be confused, as the potential landmarks available within the view are limited. Further work is essential to understand this phenomenon, and to make recommendations for military use of this product in the rural area.

The effect of specific training during presentations has not been investigated. In this case the hypothesis is that specific training on landmarks and features within an image will trigger recognition of both that image and the real environment.

It was particularly noticeable that the post walkround tests using photographs were not practicable measures for assessing spatial knowledge of the environment. There was a noticeable lack of recognition of some photographs, even in places where the researcher knew positively that all members of the group had physically visited during the days' walk. However, lack of recognition for some photographs was unwavering. This highlighted questions concerning the nature of imagery used for learning and testing purposes. The imagery used in this experiment was not taken at the season when experimentation took place (images were taken during the summer and the experiment took place in autumn), and at the time of the experiment, digital imagery was not of very high resolution. It is possible that these factors affect recognition, however recognition of some images did occur and therefore it is not considered that the fidelity and resolution of the learning and test images were major confounding factors.

Where recognition did occur, the element of the image triggering recognition could appear small and trivial (for example a plastic cover on a fence). This also highlighted questions concerning how the military participants actually deconstructed an image, and whether this was an important element for consideration in future experiments and for potential use of the toolsets.
Conclusions

The experimental tools and information were found to be useful as tools for introducing the environment and planning activities within this environment. The imagery group showed smaller errors in the initial days of the experiment, and identified more landmarks on sketch maps than the control groups.

There was a general identifiable trend towards increased recognition of the key points used for pointing and distance estimation tasks over the course of the experiment across all groups.

There was a significant effect of time and experimental condition on the error in estimated bearing to key points: the imagery group showed significantly smaller errors. Both groups showed a significant decrease in error over the course of the experiment.

The imagery group identified significantly more landmarks on the last day of testing on the sketch map test. The imagery group showed significant differences between day two and day five for the number of landmarks, nodes and features identified. Using unannotated panoramic images for spatial knowledge tests failed to elicit usable data.

There is some evidence to suggest that the experimental groups have a slightly increased knowledge of the environment, but this knowledge is not more accurate than that of the control groups, ie the experimental groups know the names of more places, but cannot pinpoint them on sketch maps with any greater accuracy.
Chapter Six

EXPERIMENT TWO: URBAN ENVIRONMENT

Background

The initial questions posed in the introduction covered the use of imagery and GIS toolsets by military personnel in both rural and urban environments. Whilst the use of urban environments is covered in previous research, as discussed in chapter two, the spatial knowledge acquisition by military personnel has not been specifically studied. In addition, there is no clear, confirmed conclusion within the available literature as to whether there is a measurable transfer of learning from a virtual to an urban environment. Therefore, it was decided that a further experiment should be conducted to attempt to provide data on this point.

The virtual environments within previous research have taken various forms, primarily within buildings, or within small sections of college campuses. The urban environment for this particular study was a small section of a town, contained within a border of roads. The area was approximately 0.5km by 1km, so was considerably smaller than the rural environment used in experiment one. The area contained a number of landmarks that would typically be expected in an urban environment: convenience stores, car parks, public houses, leisure centre, church as well as some landmarks specific to this particular environment, for example particular road junctions.

Although some findings from the rural experiment were indicative of an effect of enabling the participants to use GIS and imagery to improve their learning of the new environment in the rural situation, there is a question of whether this effect can be measured in the urban environment. Indeed, with the likely increased level of identifiable landmarks within the urban environment, it may be that the effect is increased in the urban situation.
Furthermore, as the rural experiment took place within an existing military exercise, it was not possible to determine accurately the physical learning effects (ie it was not always possible to determine where each participant had actually walked, only the general area) and to control for all the possible confounding factors.

The aims, therefore, of this experiment were to explore the contribution of virtual environments to the learning process in the urban environment, and to attempt to overcome some of the confounding factors identified in the rural experiment.

**Approach**

The approach used for experiment two, to answer the specific questions for the urban environment was developed from those methods identified from the previous research in this field. For this experiment a cross over design was deemed most suitable to answer the specific questions. Therefore all participants undertook the control condition (use of maps only) either in the first test session or the second. This would provide a point of comparison for analysis for elicitation of the effects of the imagery toolset.

Groups of participants were introduced to the experiment in their normal working locations, and were then taken on a separate day to the test location. After further time for learning the environment, they were taken on a specific route through the test location, as a group. During this walk, they were stopped at two pre-defined locations for the pointing and distance estimation tasks. On completion of the walk they were asked to complete a sketch map, as this had been discovered to be the most sensitive measure of spatial knowledge in the rural experiment.

Many of the research studies identified in the literature compared maps, virtual environments and direct navigation in some combination. The methods used to elicit the acquisition of spatial knowledge generally involved pointing tasks, Euclidean and route distance estimation, sketch maps and recall tasks. This experiment aimed to include the pointing tasks, Euclidean distance estimation and the sketch maps to identify the acquisition process for the spatial
information about this rural environment. Using these methods would allow comparison with previous research, as well as being practicable within the experimental set up.

The participants who volunteered for these experiments were made available in their normal working groups, similar to those in the rural experiment. Therefore, for each experimental session, the background and experience of the individuals participating were likely to vary. Each participant was asked to provide details of previous visits (if any) to the test location, and to provide some outline information on their role, training and background experience. Analysis was conducted on these data to investigate possible effects of these factors.

Methods

Participants

The participants for the urban test series were 136 military personnel selected from general service infantry and home service infantry units. Participants ranged in age from 17 years to 46 years. Of these 3 were female and 133 were males.

The participants reported length of service ranging from less than one year up to 29 years, with 110 participants reporting ten years or less service.

Forty of the participants reported having worked at or visited the trials location previously. Table 6-1 shows the latest reported visit for the participants who had visited the trials location previously.
Table 6-1: Frequency and latency of previous visits to the trials location by participants

<table>
<thead>
<tr>
<th>Previous visits</th>
<th>No participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current year</td>
<td>14</td>
</tr>
<tr>
<td>1 year ago</td>
<td>4</td>
</tr>
<tr>
<td>2 years ago</td>
<td>3</td>
</tr>
<tr>
<td>3 years ago</td>
<td>2</td>
</tr>
<tr>
<td>4 years ago</td>
<td>1</td>
</tr>
<tr>
<td>5 years ago</td>
<td>1</td>
</tr>
<tr>
<td>&gt; 5 years</td>
<td>2</td>
</tr>
<tr>
<td>Not supplied</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
</tr>
</tbody>
</table>

Seventy participants reported using some form of computer at home, whilst 62 participants reported no use of computing at home. Twenty participants report using computers or other information technology (IT) at work, and these individuals were primarily group or team leaders. Of those reporting use of IT at home, nineteen reported using it less than once per week, sixteen reported using it once per week and twenty-nine reported using it daily. Of the 70 reporting use of IT at home, 54 reported usage of the internet.

Participants were asked to assess their sense of direction. Table 6-2 shows the breakdown of these self assessments.
Table 6-2: Frequency of self reported sense of direction on a five point scale

<table>
<thead>
<tr>
<th>Sense of Direction</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Poor</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>Poor</td>
<td>5</td>
<td>3.7</td>
</tr>
<tr>
<td>Average</td>
<td>42</td>
<td>30.9</td>
</tr>
<tr>
<td>Good</td>
<td>53</td>
<td>39</td>
</tr>
<tr>
<td>Very Good</td>
<td>13</td>
<td>9.6</td>
</tr>
<tr>
<td>Total</td>
<td>114</td>
<td>83.8</td>
</tr>
<tr>
<td>Data not supplied</td>
<td>24</td>
<td>17.7</td>
</tr>
<tr>
<td>Grand total</td>
<td>136</td>
<td>1000</td>
</tr>
</tbody>
</table>

All participants were volunteers for these trials, and all were asked to sign a consent form agreeing to participate in the trials. Participants were given no incentives to participate in these experiments, however refreshments and confectionary were provided for each participant at the time of the experiment.

**Materials**

*Control condition*

The control condition participants were provided with paper maps and printed aerial photography of significant areas of the test area. These photographs could be printed at the request of the participants from library data.

*Imagery*

Participants from the Imagery and imagery + instruction conditions were given access to the GIS and imagery toolset for the urban trials area and they were asked to familiarise themselves with the trials area and to plan for an urban patrol.

In this condition, participants were allowed access to the basic visualisation toolset. This toolset consisted of AXIS 2000™ Geographic Information System: this is the interface for usage of the other elements of the toolset; orthorectified...
aerial photography of the new environment and the surrounding area; cartographic maps; still images (digital images of key landmarks) and panoramic images.

The researcher was available during all training sessions to assist with using the toolset. The aim of this experiment was to test the information available rather than the interface and means of accessing the information.

All participants were encouraged to use these tools to learn about the new environment area. A route for a walk through the environment was presented to the group and once complete the group were able to access the imagery toolset and encouraged to do so to learn about the environment.

**Imagery + Instruction**

In this condition, participants were given access to the same tools as for imagery only group, and they were given similar types of activity to prepare. At the end of each training period, the researcher presented a complete introduction to the new environment to the entire group, drawing attention to particular features and landmarks within the photography.

**Experimental design**

There were three experimental conditions Control group, Imagery group with access to visualisation toolset and Imagery + instruction group with access to visualisation toolset, plus specific instructions on interpreting imagery;

The experimental design was a cross over design, with each participating group undertaking two experimental conditions. The design matrix is shown at table 6-3.

Each participating group was trained using condition 1 tools, and then will undergo a further period of training during the test period for condition 2.

A priori GPOWER analysis has been conducted for a four subject group experimental design (reference 2). For an effect size of 0.15 (small effect), a of 0.05 and a power of 0.85, GPOWER analysis recommends 552 participants across 4 groups. The requested 576 participants allows for some "no-shows" in the subject population.
A smaller experimental design allowing for two groups per combination of test conditions would allow this trial to complete earlier and would require fewer participants; this would be easier to achieve and would involve a planned subject population of 384. Using the compromise analysis within GPOWER this would provide power of 0.7583 with $\alpha$ of 0.0806.

The actual number of participants available depended on the actual availability of personnel, and the timescales involved, and in the event only 136 were made available.

Table 6-3: Experimental design matrix

<table>
<thead>
<tr>
<th>Condition 1</th>
<th>Condition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Control</td>
</tr>
<tr>
<td>Control</td>
<td>Imagery</td>
</tr>
<tr>
<td>Control</td>
<td>Imagery + Instruction</td>
</tr>
<tr>
<td>Imagery</td>
<td>Control</td>
</tr>
<tr>
<td>Imagery + Instruction</td>
<td>Control</td>
</tr>
<tr>
<td>Imagery</td>
<td>Imagery</td>
</tr>
</tbody>
</table>

Where possible, participants were recruited from different work environments for each element of the design matrix.

Procedure

The experimental procedure was split into two main parts. Firstly, a pre-experimental training day: in this session the participants were introduced to the trials, and were asked to formally consent to participation in the experiment. Tests of general spatial ability were administered and participants were asked to provide spatial information about an area familiar to them (i.e., the area where
they would normally work). The second element of the experiment was within
the novel urban environment: in this part a single group undertook the test
series at a time. Each group was asked to plan a walk using the toolsets available
to them for the experimental condition. Spatial tests were administered at this
time. Further training and planning took place for the second experimental
condition for that multiple. The spatial tests will be repeated after this training
period.

The following sections describe the tests used in more detail.

**Pre-experimental training**

These tests were undertaken at a location familiar to the participants (their
own normal place of work).

Participants were taken to a specific point within familiar area and asked to
give bearings and distance to key points within that area.

Participants were given access to the visualisation toolset applicable to their
initial experimental condition for the urban trials area and they were asked to
familiarise themselves with the trials area and to plan for a walk in the
environment. The researcher was available to assist with the imagery toolset at
this point. The researcher gave an environment familiarisation talk, taking the
participants on a route through the environment (either using the maps or the
imagery as a guide); the route was planned to pass as many of the major
landmarks in the environment as possible. Landmarks missed out on the route
were pointed out at this introduction. Participants were then given time (up to 30
minutes) to learn the environment for themselves.

For the imagery+instruction group, the researcher during the familiarisation
talk gave details about each of the images and pointed out items of relevance,
for example the nature of a particular junction within an image, or the
appearance of a side alley between buildings. For this group, the researcher
instructed the participants to particularly notice areas in the images where they
felt the environment to be significant (for example where they would feel
vulnerable walking along).
Experiment within the urban environment

The experimental day in the novel environment was planned to take place within two to three days of the initial pre-experimental phase; in most cases this was achieved, however in some cases there was a delay between the pre-experimental phase and the experimental phase, this delay was outside the control of the researcher.

The training and environmental familiarisation was repeated at the start of the trial period, using the visualisation toolset appropriate to the initial experimental condition for the multiple. Research personnel were available to assist with usage of the toolset if required and the familiarisation talks were repeated. The group leader was asked to give a pre-walk introduction at the end of the training period, assisted by the researcher if requested.

The participants were taken on a walkthrough of the urban area. At two specific points during this walkthrough participants were asked to provide bearing and distance information to two key points. Key points were chosen from the list of those specifically mentioned during training, so that no key point was visible from the test location (where the participants were stopped), and so that as far as possible, successive participants (forming a queue at each point) were asked to provide information for different key points.

On return to the laboratory on completion of the walk, participants were asked to create a sketch map, showing roads, landmarks, buildings and key features to the best of their knowledge at that time.

On completion of these tests, participants underwent a further training and planning period using the visualisation toolset appropriate for the second experimental condition, using the same route and tasks as for the previous condition. Researchers were available to assist with usage of the toolset if required.

A second walkthrough was undertaken, along the same route. At the same locations, participants were stopped and asked to provide distance and bearing to two key points.
Participants were asked to create a second sketch map, showing roads, landmarks, buildings and key features to the best of their knowledge at that time.

**Summary of measurements taken**

For the pre-trials training days, the following measures were recorded: Questionnaire, a sketch map of familiar location and bearing and distance measures to key points within their own location.

For the trials within the novel environment, the following measures were recorded, from each participant:

*Table 6-4: List of measures recorded for each participant*

<table>
<thead>
<tr>
<th>First walkthrough (condition 1)</th>
<th>Second walkthrough (condition 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At each of 2 test locations, bearing and distance to 2 key points</td>
<td>At each of 2 test locations, bearing and distance to 2 key points</td>
</tr>
<tr>
<td>Sketch map of all landmarks and routes memorised for the new environment</td>
<td>Sketch map of all landmarks and routes memorised for the new environment</td>
</tr>
</tbody>
</table>

**Data descriptions**

A total of 136 participants took part in the experiment. Each participant undertook a series of pre-tests prior to travelling to the site of the experiment. Participants were grouped according to their normal working group or platoon, and multiples were randomly assigned to one of six experimental groups. Table 6-5 shows the number of participants for each experimental condition. The numbers vary, because the groups assigned were groups of either approximately 12 persons or approximately 25 persons. There were three female participants and the remainder were male.
Table 6-5: Number of participants in each experimental condition

<table>
<thead>
<tr>
<th>Experimental Condition</th>
<th>Number of participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Control</td>
<td>24</td>
</tr>
<tr>
<td>Control-Imagery</td>
<td>37</td>
</tr>
<tr>
<td>Control - Imagery+Instruction</td>
<td>24</td>
</tr>
<tr>
<td>Imagery - Control</td>
<td>23</td>
</tr>
<tr>
<td>Imagery+Instruction - Control</td>
<td>20</td>
</tr>
<tr>
<td>Imagery - Imagery</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>136</td>
</tr>
</tbody>
</table>

Each participant was asked to assess their knowledge of the new area after initial familiarisation according to their experimental condition, and tables 6-6 and 6-7 show the frequencies of response.

Table 6-6: Frequency of self assessed knowledge of the urban environment on the first test

<table>
<thead>
<tr>
<th>Assessed knowledge 1st test</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td>19</td>
<td>14.0</td>
<td>17.8</td>
<td>17.8</td>
</tr>
<tr>
<td>No knowledge</td>
<td>53</td>
<td>39.0</td>
<td>49.5</td>
<td>67.3</td>
</tr>
<tr>
<td>Poor</td>
<td>30</td>
<td>22.1</td>
<td>28.0</td>
<td>95.3</td>
</tr>
<tr>
<td>Adequate</td>
<td>5</td>
<td>3.7</td>
<td>4.7</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>78.7</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>29</td>
<td>21.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>136</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 6-7: Frequency of self assessed knowledge of the urban environment on the second test

<table>
<thead>
<tr>
<th>Assessed knowledge 2nd test</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No knowledge</td>
<td>1</td>
<td>0.7</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Poor</td>
<td>6</td>
<td>4.4</td>
<td>23.1</td>
<td>26.9</td>
</tr>
<tr>
<td>Adequate</td>
<td>16</td>
<td>11.8</td>
<td>61.5</td>
<td>88.5</td>
</tr>
<tr>
<td>Good</td>
<td>3</td>
<td>2.2</td>
<td>11.5</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>18.1</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>999999</td>
<td>80.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>136</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As with the rural tests, some participants were absent for part of the test, and this is shown as missing data. On occasions, new participants were added to the group for the experimental stage, and therefore these participants did not undergo the full pre-test sequence. Additionally, some participants who underwent the pre-test did not participate in the experiment, this was principally for military reasons, and not due to participant withdrawal.

Analysis

Spatial tests

The spatial knowledge test results were recorded as a relative bearing and a distance in metres. The location of the test site was recorded as an eight figure grid reference. A true bearing and distance was calculated from the test location to the grid reference of the key point.

The difference between the estimated bearings and distances and the true bearings and distances were calculated by simple subtraction to create an error measure for both distance and bearing. The distance errors were calculated as a percentage of the true distance (with errors in excess of the true distance reduced to 100%). The bearing errors were calculated as a percentage of the maximum bearing error possible (ie 180°). These errors were averaged over the test and the day for further analysis.
Sketch map tests

Each participant created two sketch maps of the novel area. These were graded for the appearance, suitability as a map and pictorial content. A landmark on the sketch maps was defined as a building, specific delineated area with dimensions (for example a gateway or fire muster point) or a specific named road junction. To be included in the analysis, the landmark had to be identified by a symbol and a name on the sketch map, the only exceptions to this were buildings of such specific shape that they were identifiable (for example the only E shaped building on the site).

The number of landmarks, nodes, features and districts was counted. Only those maps with at least four, five or six landmarks were used for further analysis; the appropriate number of identifiable landmarks were selected and the distances and bearings between each pair of landmarks were measured (depending on the number available and identifiable for each sketch map). The distance of each landmark to each other landmark was measured in millimetres using a standard ruler. The bearing of each landmark to each other landmark was measured using a standard scholastic protractor, for a given orientation of the sketch map (the same orientation for each environment) to an accuracy of 5°. These distances and bearings were calculated for the true positions taken from planning drawings for each site for the pretest maps. The true positions and bearings were calculated from 8 figure grid references taken from an orthorectified GIS image for the urban experimental environment.

An average relative bearing and relative distance error for each participant for each map was calculated and used for the analysis.
Results

For each graph, where error bars are shown these are 95% confidence limits of the mean unless otherwise stated.

Descriptives

A frequency analysis of the number of participants for each experimental condition is shown in table 6-3. As the participants were allocated to the experimental conditions by their originating units, and groups of varying size were sent to the trials location, the numbers varied outside the control of the researcher. A further factor was that participants who were originally allocated to a particular experimental time, could either be reassigned to alternative times or alternative duties. Substitutes were sometimes provided but not always.

Pretest measurements:

A one-way ANOVA was conducted across all the pretest measurements using experimental condition as a factor. This aimed to test whether there were any significant differences between the groups in terms of their spatial ability. Significant differences ($p<0.05$) were observed in the pretest bearing differences (although not the percentage errors), the pretest map errors in location of key points (both in distance and bearing) and the pretest map number of features.

For the error in estimated bearing, the control-control group showed significantly greater errors than any of the other groups.

For the map tests, the Imagery+instruction-control group showed significantly smaller distance errors in landmark location than any of the other groups. The imagery-control and imagery-imagery groups showed significantly greater bearing errors in landmark location on the sketch maps than the remaining groups.

Although these effects are significant, a high proportion of the participants did not undertake or complete these tests, and therefore it was decided that all cases should be included in the analysis of the test results.
Analysis of the pretest measurements showed considerable variability in the performance of the individuals in an area with which they were familiar. Figure 6-1 shows a scatter plot of the actual difference in estimated to true bearing against the self assessed sense of direction.

![Figure 6-1: Scatter plot of mean difference between estimated and true bearings to familiar landmarks.](image)

*Sense of direction is given as a five point scale where 1= Very poor, 3=adequate and 5=very good*

As can be seen from figure 6-1, there is a considerable range in the ability of the individuals to estimate a bearing to a familiar landmark.

**Experimental measurements in the novel urban environment**

A mixed two-way ANOVA with experimental condition by error in estimated bearing to key points for all participants in tests 1 and 2 showed an effect approaching significance for time and condition ($F=2.291$ (1,5) $p=0.052$). These
results are shown graphically in figure 6-2. However, Bartletts test of sphericity shows that the variables are not correlated.

Figure 6-2 shows that there are noticeable, although not significant from this test, differences between the groups, and between test sessions one and two. The control-control group showed an increase in error between the test sessions, all the remaining groups showed a decrease in error, although for the control-imagery+instruction and the imagery+instruction-control groups this decrease was minor.

Using a one-way ANOVA on by error in estimated bearing to key points with experimental condition as a factor, there is no significant effect of experimental condition on the bearing error in the initial test. However, this one-way ANOVA did identify a significant effect of experimental condition in the bearing error on the second test ($F=3.4$ (5,98), $p<0.01$).

A mixed two-way ANOVA was conducted on the error in estimated distance to key points in test sessions one and two by experimental condition. Again, both
Bartlett's and Mauchly's tests of sphericity showed that these variables were not correlated, and therefore multivariate tests were not indicated. These results are shown graphically in figure 6-3.

![Mean estimated distance error](image)

**Figure 6-3:** Mean estimated distance error to key points by experimental condition for each test session.

Of the experimental groups, the control-imagery and imagery-imagery groups both showed an increase in error between test session 1 and test session 2.

One-way ANOVAs were conducted on the distance errors in each test session using experimental condition as a factor. A significant effect of experimental condition was found on the distance error on the first test session ($F=5.07 (5,89), p<0.01$).

However, a number of participants did not record a distance estimation in the test sessions, and therefore the number of participants in each of these groups is reduced. Table 6-8 shows the number of participants who recorded
distance estimations compared to the total number of participants for each experimental condition.

Table 6-8: Number of participants recording a distance estimation compared to total number of participants for each experimental group

<table>
<thead>
<tr>
<th>Experimental condition</th>
<th>Total number of participants</th>
<th>Number of participants recording distance estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Control</td>
<td>24</td>
<td>6</td>
</tr>
<tr>
<td>Control-Imagery</td>
<td>37</td>
<td>23</td>
</tr>
<tr>
<td>Control-Imagery+Instruction</td>
<td>24</td>
<td>11</td>
</tr>
<tr>
<td>Imagery-Control</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Imagery+Instruction-Control</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>Imagery-Imagery</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>136</td>
<td>83</td>
</tr>
</tbody>
</table>

In order to elicit any effects of the order (either first or second) in which the participants experienced the control condition, two experimental conditions were excluded from the analysis (the control-control and imagery imagery groups). A mixed two way ANOVA was conducted on the error in estimated bearing by the order of experiencing the control condition. A significant effect of time was found ($F=4.76$ (1,87), $p<0.05$) but no significant effect of order.

There was no effect of order on the error in estimated distance to landmarks.
**Sketch map analysis**

A mixed two way ANOVA was conducted on each of the sketch map variables by experimental condition.

For the mixed two way ANOVA on number of landmarks by experimental condition and test session, both Bartlett's and Mauchly's tests of sphericity are significant, showing that multivariate tests cannot be used for these data. A summary of the data are shown graphically in figure 6-4.

![Figure 6-4: Number of landmarks recorded on sketch maps by experimental condition for each test session.](image)

There is a noticeable increase in the number of landmarks identified on the sketch maps between session one and session two, for the control-control, control-imagery and the imagery+instruction-control groups, these increases are significant.

One-way ANOVAs were conducted on the sketch map variables using experimental condition as a factor. Significant effects of condition were found on the number of landmarks in the first sketch maps ($F=7.68 (5, 130), p<0.01$) and the second sketch map ($F=7.08 (5, 122), p<0.01$). Significant effects of
Significant effects of experimental condition were found on the number of nodes on the first sketch map \((F=6.29 (5, 130), p<0.01)\) and the second sketch map \((F=5.66 (5, 122), p<0.01)\). Significant effects of experimental condition were found for the number of districts on the first sketch map \((F=6.04 (5, 130), p<0.01)\) and the second sketch map \((F=4.03 (5, 122), p<0.01)\). Significant effects of experimental condition were found for the number of features on the first sketch map \((F=4.95 (5, 130), p<0.01)\) and the second sketch map \((F=4.94 (5, 122), p<0.01)\). No significant effects of experimental condition were found on the errors in landmark location for any of the sketch maps. These results are shown graphically in figures 6-5 and 6-6.

![First Sketch Map](image-url)

**Figure 6-5**: Number of landmarks, nodes, districts and features on the first sketch map by experimental condition.

In the first sketch map, the group receiving the control condition first with imagery and instruction second, identify significantly more landmarks and nodes than other groups, including those other groups receiving the control condition first.
For the second sketch map, the group receiving imagery condition first, but control second identify significantly fewer landmarks than the other groups. The control first with imagery plus instruction second appear to identify significantly more nodes than other groups.

Mixed two-way ANOVAs were conducted on the error in landmark location on the sketch maps (bearing and distance), the number of features, nodes and districts identified on the sketch maps by test session (first and second) and experimental condition. Both Bartlett's and Mauchly's tests of sphericity are significant for each of these tests, showing that multivariate tests cannot be used for these data.

The results for the bearing error in landmark location are shown graphically at figure 6-7.
Figure 6-7: Mean bearing error in sketch map landmark location by experimental condition for each test session.

From figure 6-7 it can be seen that there is an effect of learning the environment in that the error is reduced in all experimental groups. This effect is not apparent for the distance error in landmark location, where the mixed two-way ANOVA using experimental condition as a factor failed to elicit any significant effects.

The number of nodes created on the sketch maps results are shown graphically in figures 6-8.
In all experimental conditions, the number of nodes created on the sketch maps increased in session two from session one. For the control-control group and the control-imagery group, these differences are significant.

As for the spatial tests, mixed two-way ANOVAs were conducted on the sketch map tests to investigate any effect of the order of experiencing the control condition. Mixed two way ANOVAs were conducted on each of the sketch map variables, by the order of experiencing control condition (first or second). No significant effect of order was elicited.

### Effect of previous visits

Of the 136 total participants, 37 reported having visited the test location previously (sixteen participants failed to report whether or not they had previously visited). Table 6-9 shows the number of participants and percentage who have visited the test location before by experimental group.
Table 6-9: Number of participants who have visited the test location previously

<table>
<thead>
<tr>
<th>Visit test location before</th>
<th>Total No participants</th>
<th>% visited previously</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Control-Control</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>Control-Imagery</td>
<td>27</td>
<td>8</td>
</tr>
<tr>
<td>Control-Imag+Instr</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>Imagery-Control</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>Imag+Instr-Control</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Imagery-Imagery</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>83</td>
<td>37</td>
</tr>
</tbody>
</table>

Repeated measures ANOVAs using both experimental condition and visited test location before as factors failed to elicit any significant effects of previous visits to the test location on the spatial tests of bearing and distance errors to key points. The same analyses performed on the sketch map variables only elicited a significant effect of test session, experimental condition and visited before on the number of landmarks created on the sketch maps ($F=3.004 (1,5), p<0.05$), all other effects were not significant. Figure 6-9 shows the effect of experimental condition and previous visits on the number of landmarks.
There is a trend towards an increased number of landmarks created by those who have visited the test site previously, and for some groups this effect is significant. A one-way ANOVA for the control-imagery+instruction group using previous visit as a factor shows a significant effect of previous visit on the number of landmarks created on the first map, but not on the second ($F=5.228, (1,1), p<0.05$ for the number of landmarks on the first sketch map).

**Effect of self reported sense of direction**

Of the 136 participants in total, 115 provided a self assessed report of their sense of direction on a five point scale. Table 6-10 and figure 6-10 show the breakdown of the reported sense of direction by experimental condition.
Table 6-10: Frequency of self reported sense of direction scales by experimental group

<table>
<thead>
<tr>
<th></th>
<th>Very Poor</th>
<th>Poor</th>
<th>Average</th>
<th>Good</th>
<th>Very Good</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Control</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>9</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Control-Imagery</td>
<td>1</td>
<td>2</td>
<td>13</td>
<td>14</td>
<td>4</td>
<td>34</td>
</tr>
<tr>
<td>Control-Imag+Instr</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>10</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>Imagery-Control</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>11</td>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>Imag+Instr-Control</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>Imagery-Imagery</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>5</td>
<td>42</td>
<td>53</td>
<td>13</td>
<td>115</td>
</tr>
</tbody>
</table>
A mixed two-way ANOVA was conducted on the variables measured during this experiment, using sense of direction and experimental condition as factors. Both Bartlett’s and Mauchly’s tests of sphericity are significant, showing that multivariate tests cannot be used for these data.

**Principal Components Analysis**

Principal components analysis was conducted on all the available measures. Using Direct Oblimin rotation, and a simple Eigen Values in excess of 1.0, five factors were extracted during exploratory factor analysis.
From the pattern matrix for this analysis, it can be seen that the sketch map number of features (for both test sessions one and two) and the average distance error in the spatial tests are the principle variables loading onto factor one (loadings greater than 0.4).

The distance errors in location of landmarks on the sketch maps are the main variables loading onto factor two.

The bearing errors in location of landmarks on the sketch maps and the number of landmarks for both sketch maps load onto factor three.

The number of nodes on both sketch maps loads onto factor four.

The initial test bearing error in location of landmarks and the second test distance error in placing landmarks loads on the final factor.

A one-way ANOVA using experimental condition as the factor was conducted on the regression factors elicited from the principle components analysis, this revealed that there was a significant effect of condition on factor
one \( (F=9.840 (1,4) \ p<0.01) \), factor three \( (F=4.426 (1,4), \ p<0.01) \) and factor four \( (F=2.542 (1,4), \ p<0.05) \).

**Performance prediction**

Simple Pearson correlations were assessed between the pretest measurements and the measurements within the new environment. Some significant correlations were found (for example the pretest distance error is correlated with the second sketch map number of nodes \( (\alpha=0.34 \ p<0.05) \). The number of landmarks in the pretest sketch maps of the familiar area correlates with a number of the measurements taken in the new environment. Table 6-12 shows these correlations in more detail.

Table 6-12: Summary of the significant simple correlations between the number of landmarks in the pretest sketch map and the test measurements in the new environment

<table>
<thead>
<tr>
<th>New environment measurement</th>
<th>Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 2 Average bearing error</td>
<td>( \alpha=-0.27 \ p&lt;0.01 )</td>
</tr>
<tr>
<td>Map 2 average bearing difference</td>
<td>( \alpha=-0.28 \ p&lt;0.01 )</td>
</tr>
<tr>
<td>Map 1 number of districts</td>
<td>( \alpha=0.30 \ p&lt;0.01 )</td>
</tr>
<tr>
<td>Map 1 number of landmarks</td>
<td>( \alpha=0.48 \ p&lt;0.01 )</td>
</tr>
<tr>
<td>Map 1 number of nodes</td>
<td>( \alpha=0.35 \ p&lt;0.01 )</td>
</tr>
<tr>
<td>Map 2 number of districts</td>
<td>( \alpha=0.32 \ p&lt;0.01 )</td>
</tr>
<tr>
<td>Map 2 number of landmarks</td>
<td>( \alpha=0.52 \ p&lt;0.01 )</td>
</tr>
<tr>
<td>Map 2 number of nodes</td>
<td>( \alpha=0.38 \ p&lt;0.01 )</td>
</tr>
<tr>
<td>Map 2 number of features</td>
<td>( \alpha=0.44 \ p&lt;0.01 )</td>
</tr>
</tbody>
</table>
Discussion

Summary of results

A total of 136 participants took part in this experiment, and were divided (within their normal working groups) into six experimental categories. The experimental design was a cross over, with each group (excepting eight participants) experiencing the control condition (maps only) either in the first learning and test session or the second.

Pre test measurements conducted at a location familiar to the participants (their normal working environment) showed some variability in performance at the measures used.

Spatial tests

Most of the experimental groups showed a decrease in the error in estimated bearing between test session one and two; the exception being the control-control group, however these effects were not shown to be significant. There was no significant effect of experimental condition identified for the bearing error for the first test, however the second test session did show a significant effect of experimental condition, in that the control-control group produced significantly greater errors than the control-imagery or imagery-imagery groups.

Most of the experimental groups showed a decrease in the error in estimated distance between test session one and two; the exception being the control-imagery and the imagery-imagery groups, however these effects were not shown to be significant. There was a significant effect of experimental condition identified for the distance error for the first test, in that the control-control group produced significantly greater errors than any of the other groups; however the second test session did not show a significant effect of experimental condition.

Sketch map

All groups identified more landmarks on the second test compared to the first test, however this effect was not shown to be significant. There were
significant effects of condition on a number of the sketch map variables for each of the first and second test sessions.

Previous visits

A number of the participants reported that they had previously visited the test location, however the effect of previous visits was not shown to be significant on the variables measured.

Sense of direction

No overall effect of sense of direction was elicited for the dependent variables measured.

Principal Components Analysis

Principal components analysis elicited five factors; using the regression factors derived from the analysis showed significant effects of experimental condition on three of these factors.

Overview

The literature suggests that participants learning from maps should acquire survey knowledge and those learning from experience should acquire route knowledge. It was anticipated that the addition of imagery to the learning process would enhance the route knowledge acquisition, since a simulated route was presented to the participants. From the sketch map data, it would appear that participants had acquired some degree of survey knowledge, although the accuracy of this data was variable. The sketch map data proved to be the most sensitive measure to determine the effect of experimental condition. However analysis of the data showed no effect of specific instruction on the participants’ acquisition of spatial knowledge about the novel environment. This would suggest that learning in this environment does not depend on the specific instructions to analyse the imagery used in the tests. The sketch maps showed significant effects of experimental condition on the number of landmarks produced on the sketch maps: however there is an experimental artefact in that the control-imagery+instruction group show a significantly greater number of landmarks in the first sketch map. It is possible that this is due to increased
application to the learning process, it was observed that some groups were more conscientious in learning from maps than others.

**Pretest measurements**

Considerable variability in performance was observed with these participants, even within an area familiar to them. This concurs with Wilson et al (1997) who concluded that effects were likely to be small and easily masked by individual variability in performance.

**Spatial tests**

Significant effects of experimental condition were identified in the spatial tests. The control-control group showed an increase in error between test session one and two, which was in contrast to the remainder of the groups, and this measurement on the second session was significantly greater than performance by the control-imagery and imagery-imagery groups. The reason for this apparent decrease in performance by this group is not apparent from the data.

Two of the experimental groups showed a decrease in performance in distance estimation between the two tests sessions: the imagery-imagery group and the control-imagery group. The reason for this decrease in performance is not apparent from the data.

**Sketch map tests**

The fact that the sketch map measures show the most significant effect of experimental condition and learning, would tend to suggest that the participants are acquiring survey knowledge. However, survey knowledge would tend to be associated with increased ability to estimate Euclidean distances between key points, and this measure shows no significant learning or condition effect for any of the experimental groups.

The high recognition of landmarks and key points during the tests would support the conclusion that the participants are acquiring route knowledge of the environment. The recognition of the landmarks overall is very high (averaging greater than 80% of the presentations), and show no trends between
experimental groups, which would suggest that learning strategies for the use of the imagery toolset are not improving route knowledge over the existing learning strategies from a map.

**Other effects**

The effects of gender on spatial learning and ability were not analysed in this experiment since there were only three females in the initial participant set. Whilst the literature suggests an effect of gender on learning and ability, it was not possible to confirm this effect within this population.

In this experiment, no overall effect of sense of direction on performance or learning was shown, this is in contrast to Kozlowski and Bryant (1977), who showed that those with a self reported good sense of direction performed better than those with a poor sense of direction.

**Principal components analysis**

Within the previous literature covered during this research, principal components analysis has not been conducted on the data obtained. Within this research five factors were derived, and significant effects of experimental condition were observed with three of these (factor one: number of features and average distance errors; factor three: bearing errors in sketch map landmarks and number of landmarks and factor four: the number of nodes).

**Prediction of performance**

The number of landmarks in the pretest sketch map was shown to correlate with a number of the test variables measured, particularly the sketch map tests. This measure could potentially be used as a predictor of performance for learning a new environment.

**Confounding factors**

A number of confounding factors were identified in the data obtained through this experiment: previous visits to the test location, sense of direction, gender and learning styles. Data were not collected on learning styles, since the
large number of participants tested at a single session made individual observation difficult. However, Allen and Willenborg (1998) showed that distractions and concurrent tasks did impact on performance and Thorndyke and Stasz (1980) showed that a systematic approach to learning improved performance. It is clear that the instructions provided to the participants (imagery+instruction group) did not have a significant impact on the performance during the spatial or sketch map tests. Therefore, it is likely that some training in the systematic learning approaches may improve learning and performance. However, Kinnear and Wood (1987) showed no effect of formal geography training on the outcome. This would suggest that the learning of spatial information is complex.

Conclusions

Considerable variability in performance was observed with these participants, even within an area familiar to them.

In this experiment, no overall effect of sense of direction on performance or learning was shown.

Principal components analysis elicited five factors; using the regression factors derived from the analysis showed significant effects of experimental condition on three of these factors.

All groups identified more landmarks on the second test compared to the first test, however this effect was not shown to be significant. There were significant effects of condition on a number of the sketch map variables for each of the first and second test sessions.
Chapter Seven

EXPERIMENT THREE: IMAGE COMPONENTS

Background

From experiment one it was observed that participants did not always recognise images of locations in the new environment, even when they had recently walked past these locations. This lack of recognition was forthright and raises some important questions if this type of technology is to have a practical use. There are questions of fidelity and resolution of the images used as test stimuli; in some cases the resolution was poor and the images had been taken in a different season to that in which the experiment took place. However for some images, it is thought that these factors do not account for the particularly low recognition rate observed\(^3\). Anecdotal evidence from one of the test sessions suggested that the participants in this experiment were looking for particular features of an image to aid recognition (in one case, a participant recognised a location by the piece of plastic tubing covering a portion of the barbed wire fence). This raised the question of whether specific training or instruction in deconstructing the images would lead to improved recognition.

The second experiment, the urban trials attempted to investigate the effect of specific instructions at the point of learning. However, this urban experiment did not show any effect of specific instruction on the learning of the new environment.

This third experiment aimed to investigate the effect of the background, experience and general training of the participants on their deconstruction of images. Different military specialisations involve different initial training, and it is thought likely that these differences may have an impact on the analysis of

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\(^3\) Images for this environment were taken over several periods, with some months separating these. In the first image capture sessions, a low resolution camera was used, in later sessions a higher resolution camera was used, therefore the resolution of the learning and test images varied across the environment.
imagery. Therefore a range of military specialisations were recruited to participate in this experiment. As personnel are promoted, they will perform different roles within the organisation; therefore different roles are likely to have received different training and experiences. It is possible that the recognition of components could differ between these roles. This experiment aims to investigate the effect of role and specialisation on the recognition of image components.

From the literature surveyed, the explicit effects of training, experience and instructions on the recognition of components within a scene have not been evaluated. However, for the likely applications for this type of toolset within the military, the impact and effect of training and experience are valuable guidance to the applicability of the tools and the training requirements for optimum use of such tools.

Much work in the literature has concentrated on simple environments, and stylised components, it was decided that the effects of real world images should be investigated using participants with a variety of backgrounds, but who would be likely users of such technology should a system be implemented.

Some of the panoramic imagery from the previous experiments was used for this experiment, and participants were recruited who had not undertaken any previous research with this type of toolset. Participants were recruited from a variety of military specialisations and undertook this experiment in groups of between one and twenty participants at a time. All participants were asked to provide details of their current role and specialisation, and participants were recruited to cover a range of roles as well as specialisations.

The roles of these participants were either specialist (for example engineers or geographic surveyors) or functional (either group leaders with responsibility for a group of subordinates, or team leaders with responsibility for small teams of usually four individuals or team members). Group leaders and team leaders are likely to have received more training, including some orientation and map reading training than team members.
Terminology

In this chapter the term particular point is used to describe a landmark or feature of the environment that has particular significance to the military user: this may be because such a feature is a distinguishing element of the environment aiding way finding, or because such a feature is an area where they may consider they would be vulnerable.

Participants

All participants were volunteers for these trials, and all were asked to sign a consent form agreeing to participate in the trials.

Participants were selected from units made available by the military command, and were given no incentive to participate. Due to the short nature of these experiments, no refreshments were provided.

In total, 85 participants took part in this experiment, from five different types of military specialisation. Within these groups, a number of different roles were represented, each role having different training and experience backgrounds. Tables 7-1 and 7-2 show the frequency distributions of each of these characteristics.
### Table 7-1: Frequency distribution of participants by type of military specialisation

<table>
<thead>
<tr>
<th>Military specialisation</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infantry</td>
<td>30</td>
</tr>
<tr>
<td>Specialist</td>
<td>8</td>
</tr>
<tr>
<td>Other</td>
<td>7</td>
</tr>
<tr>
<td>Engineers</td>
<td>21</td>
</tr>
<tr>
<td>Engineers with survey and geographic specialisation</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>85</td>
</tr>
</tbody>
</table>

### Table 7-2: Frequency distribution of participants by type of military role

<table>
<thead>
<tr>
<th>Military role</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specialist</td>
<td>6</td>
</tr>
<tr>
<td>Senior NCO</td>
<td>12</td>
</tr>
<tr>
<td>Officer</td>
<td>5</td>
</tr>
<tr>
<td>Technical</td>
<td>14</td>
</tr>
<tr>
<td>Team leader</td>
<td>23</td>
</tr>
<tr>
<td>Team member</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>85</td>
</tr>
</tbody>
</table>
Methods

Participants were allocated to these trials in their normal working groups, with the exception of the specialists who were interviewed singly.

Participants were divided in two groups, where possible an originating unit supplied two groups: one for each experimental condition. However the number of participants turning up to these sessions was outside the control of the researcher and therefore the numbers of participants in each experimental group varied. The tests took place in either a lecture hall or classroom environment for large groups and in an office environment for those interviewed singly. Panoramic images were displayed using a laptop and projector. Images were rotated by the researcher at approximately the same speed each time, showing one complete rotation approximately every 30 seconds.

Participants in their groupings were assigned to one of two groups: “Prominent” – asked to identify prominent landmarks of the landscape that could be used for way finding or directing others around the environment and “Specific” – asked to identify particular points, instructions for this group were similar to those given to the imagery+instruction group for the urban experiment.

Table 7-3 shows the breakdown of participant origin by experimental condition.
Table 7-3: Distribution of participants by origin of military specialisation and experimental condition

<table>
<thead>
<tr>
<th>Military specialisation</th>
<th>Prominent</th>
<th>Specific</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infantry</td>
<td>20</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>Specialists</td>
<td>7</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Engineers</td>
<td>11</td>
<td>10</td>
<td>21</td>
</tr>
<tr>
<td>Engineers with survey and geographic specialisation</td>
<td>6</td>
<td>13</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>47</td>
<td>38</td>
<td>85</td>
</tr>
</tbody>
</table>

The single specialist case in the specific condition was excluded from further analysis.

Each subject was provided with a clipboard and a questionnaire to capture details of their role and specialisation, and providing space to for them to list details of each panorama presented. The aims of the trial and the questions to be answered were explained before participants consented to participation.

The subjects were shown a total of ten images: seven rural and three urban. Of each series, two were shown as a sequence, ie two images of adjacent stretches of the area or road that were shown together. With the exception of these sequences the images were shown in changing order to control for order effects on subject motivation.
Each photograph was shown for approximately three minutes, therefore the total time required for each trial set was no longer than 45 minutes. Images were displayed using either a laptop and projector or a PC monitor.

**Test material**

The test photography was selected to provide a wide range of types of terrain, including straight roads, junctions, and features. Table 7-4 shows the features that were included in the test images.

*Table 7-4: Summary description of the test panoramas used in the experiment*

<table>
<thead>
<tr>
<th>Panorama no</th>
<th>Series</th>
<th>Road features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rural</td>
<td>Junction</td>
</tr>
<tr>
<td>2</td>
<td>Urban</td>
<td>No junction</td>
</tr>
<tr>
<td>3</td>
<td>Urban</td>
<td>No junction</td>
</tr>
<tr>
<td>4</td>
<td>Rural</td>
<td>No junction</td>
</tr>
<tr>
<td>5</td>
<td>Rural</td>
<td>No junction</td>
</tr>
<tr>
<td>6</td>
<td>Rural</td>
<td>Junction</td>
</tr>
<tr>
<td>7</td>
<td>Urban</td>
<td>Junction</td>
</tr>
<tr>
<td>8</td>
<td>Rural</td>
<td>Junction</td>
</tr>
<tr>
<td>9</td>
<td>Rural</td>
<td>No junction</td>
</tr>
<tr>
<td>10</td>
<td>Rural</td>
<td>No junction</td>
</tr>
</tbody>
</table>

In the above table, photographs two and three are a linked series taken along the same stretch of path or road. Also photographs nine and ten are a linked series.

The images used for these tests are shown in the figures below, although for presentation in this thesis the images have had to be stretched into a two
dimensional format. For presentation during the test sequences, these were shown as panoramic images.

**Test images**

![Figure 7-1: Panorama one](image)

![Figure 7-2: Panorama two](image)

![Figure 7-3: Panorama three](image)

![Figure 7-4: Panorama four](image)
Analysis

The results obtained from each participant were transcribed and entered into an overall MS Excel spreadsheet. From this the total number of components for each image for each participant was calculated. The actual features of the image for each participant was recorded in full. For analysis these features were collated into categories of similar features (for example, all road and street signs were collated into a single category. The categories were identified from analysis of the results obtained. The categories used in the analysis are listed in table 7-5.

Table 7-5: Definition of the components of the images extracted from the participants analysis

<table>
<thead>
<tr>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>No components</td>
</tr>
<tr>
<td>Lone tree/treeline</td>
</tr>
<tr>
<td>Gates/barriers</td>
</tr>
<tr>
<td>Road features</td>
</tr>
<tr>
<td>Contours</td>
</tr>
<tr>
<td>Buildings</td>
</tr>
<tr>
<td>Signs</td>
</tr>
<tr>
<td>Fence/walls</td>
</tr>
<tr>
<td>ditch/culvert</td>
</tr>
<tr>
<td>Particular point</td>
</tr>
</tbody>
</table>
Gates and barriers are analysed separately from fences and walls as to these participants they form distinct entities and are treated differently. Results from individual panoramas were analysed separately and these are presented at annex D.

Once collated, the results were compressed for analysis, by summing the total numbers of image components. Results were analysed for the total across all ten panoramas and for the total number of components for the three urban and seven rural panoramas separately.

Results

Overview

Where error bars are shown in the following graphs, the bars represent 95% confidence levels of the mean.

Number of components

The number of image components identified by each group of participants was analysed. One-way ANOVAs were conducted to elicit effects of experimental condition, role and specialisation. The data for each individual panoramic image is contained in annex D.

For each participant, the total number of components across all ten panoramas, for the three urban panoramas and for the seven rural panoramas was calculated.

Mixed two-way ANOVAs using experimental condition (prominent or specific) by role on the total number of components across all ten panoramas and for the urban and rural sets respectively were conducted. These showed a significant effect of role ($F=3.88$ (5,73) $p<0.01$ for the total number of components; $F=3.44$ (5,73) $p<0.01$ for the total number of components in urban panoramas and $F=3.97$ (5,73) $p<0.01$ for the total number of components in rural panoramas). These results are shown graphically in figure 7-10. No significant effect of condition or the interaction between condition and role was identified.
In each of the following graphs, there were no specialists for the specific experimental condition.

Figure 7-10: Total number of components recorded across all ten images

From figure 7-10, it can be seen that the team leader role appears to identify fewer components than the other categories. There is no overall trend for differences between the experimental groups.

Figure 7-11: Total number of components recorded across all three urban images
In figure 7-11, there are fewer components identified in total, since there were only three urban images. The specialist and the technical roles, particularly those in the specific group, identify more components in the urban image than other roles.

![Total number of components rural](image)

Figure 7-12: Total number of components recorded across all seven rural images

From figure 7-12, the team leader role identified fewer components than the other roles.

Mixed two-way ANOVAs using experimental condition (prominent or specific) by specialisation on the total number of components across all ten panoramas and for the urban and rural sets respectively were conducted. These showed a significant effect of specialisation ($F=9.07 (4,74) \ p<0.01$ for the total number of components; $F=8.62 (4,74) \ p<0.01$ for the total number of components in urban panoramas and $F=8.28 (4,74) \ p<0.01$ for the total number of components in rural panoramas). These results are shown graphically in figure 7-13. No significant effect of condition or the interaction between condition and specialisation was identified.
From figure 7-13, the geographic specialists identified more components in all categories than other specialisations and this difference was significant; specialists and engineers identified more components than the other groups.

Types of component

Mixed three way ANOVAs were conducted on the total number of each category of component recorded to examine the effect of role, specialisation and experimental condition. No significant effect of experimental condition alone was elicited. There was a significant effect of specialisation on all parameters except the number of ditches and culverts identified. These results are summarised in table 7-6. Significant effects of role were identified for the number of road features and the number of contours identified ($F=3.90 (5,57) p<0.01$ and $F=4.76 (5,57) p<0.01$ respectively). The number of buildings identified showed a significant interaction between experimental condition and role ($F=2.699 (4,57) p<0.05$). The number of road features and the number of contours identified showed a significant interaction between experimental condition and specialisation ($F=3.90 (5,57) p<0.01$ and $F=4.76 (5,57) p<0.01$ respectively).
The number of road features, the number of contours, the number of buildings and the number of particular points all showed significant interactions between specialisation and role ($F=2.53 (9,57) p<0.05$, $F=2.54 (9,57) p<0.05$, $F=2.77 (5,57) p<0.01$ and $F=2.99 (9,57) p<0.01$ respectively).

Table 7-6: Categories of component showing a significant effect of specialisation

<table>
<thead>
<tr>
<th>Category</th>
<th>Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trees</td>
<td>$F=2.83 (4,57) p&lt;0.05$</td>
</tr>
<tr>
<td>Number of gates</td>
<td>$F=2.85 (4,57) p&lt;0.05$</td>
</tr>
<tr>
<td>Number of road features</td>
<td>$F=11.89 (4,57) p&lt;0.01$</td>
</tr>
<tr>
<td>Number of contours</td>
<td>$F=6.22 (4,57) p&lt;0.01$</td>
</tr>
<tr>
<td>Number of buildings</td>
<td>$F=4.63 (4,57) p&lt;0.01$</td>
</tr>
<tr>
<td>Number of signs</td>
<td>$F=4.53 (4,57) p&lt;0.01$</td>
</tr>
<tr>
<td>Number of fences</td>
<td>$F=2.59 (4,57) p&lt;0.05$</td>
</tr>
<tr>
<td>Number of particular points</td>
<td>$F=5.56 (4,57) p&lt;0.01$</td>
</tr>
</tbody>
</table>

The effect of role is summarised graphically at figures 7-14 and 7-15.
Figure 7-14: Total number of components recorded across all ten images by participant role

The specialist role identified more road features, contours and trees than other roles, and the difference for road features was significant. Overall, all the roles identified more road features than any of the other categories of component. The team member role identified more trees than all other roles except the specialists.
Overall, all roles identified fewer buildings, signs, fences and particular points than other categories of component. The specialists identified more buildings than other roles, and this difference was significant. The specialists identified more signs than other groups, with the exception of the technical and team member roles. The team members identified more fences than other roles.

There were differences in the types of component identified by each of the groups and the significant findings are outlined in table D-12 at Annex D.

**Effect of presentation order**

The effect of presentation order on the number of parameters identified was examined, and as would be expected there is a significant effect. A MANOVA was conducted on panorama ten to elicit multivariate effects of presentation order and originating unit. Significant effects of both unit and presentation order were shown. For panorama ten, the significant effects of presentation order were further analysed using a one-way ANOVA to discriminate the effects, and these are summarised in table 7-7.
Table 7-7: The effect of presentation order on the various parameters for panorama ten

<table>
<thead>
<tr>
<th>Parameter</th>
<th>F Statistic</th>
<th>Presentation order showing the significant effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of components</td>
<td>F=4.587 (1,76) P&lt;0.01</td>
<td>Presentation 10 significantly greater</td>
</tr>
<tr>
<td>Number of contours</td>
<td>F=3.800 (1,76) P&lt;0.01</td>
<td>Presentation 9 significantly greater</td>
</tr>
<tr>
<td>Number of buildings</td>
<td>F=4.582 (1,76) P&lt;0.01</td>
<td>Only presentation 10 identified buildings</td>
</tr>
<tr>
<td>Number of fences/walls</td>
<td>F=6.032 (1,76) P&lt;0.01</td>
<td>Presentation 10 significantly greater</td>
</tr>
</tbody>
</table>

Presentation order shows significant correlation with the number of components ($\alpha=0.226$) and the number of buildings ($\alpha=0.260$) for panorama ten; both correlations are significant at the 0.05 level.
Discussion

Summary of results

The results obtained showed a significant effect of role on the number of components identified. No significant effect of condition or the interaction between condition and role was identified. It was observed that the team leader role appeared to identify fewer components than the other categories. The specialist and the technical roles, particularly those in the specific group, identified more components in the urban image than other roles. The team leader role identified fewer components than the other roles.

The results showed a significant effect of specialisation, but no significant effect of condition or the interaction between condition and specialisation was identified. The geographic specialists identified more components in all categories than other specialisations and this difference was significant; specialists and engineers identified more components than the other group.

Significant effects of specialisation were identified on a number of component types. Significant effects of role were identified for the number of road features and the number of contours identified. The number of buildings identified showed a significant interaction between experimental condition and role. The number of road features and the number of contours identified showed a significant interaction between experimental condition and specialisation. The number of road features, the number of contours, the number of buildings and the number of particular points all showed significant interactions between specialisation and role. The specialist role identified more road features, contours and trees than other roles, and the difference for road features was significant. Overall, all the roles identified more road features than any of the other categories of component. The team member role identified more trees than all other roles except the specialists Overall, all roles identified fewer buildings, signs, fences and particular points than other categories of component. The specialists identified more buildings than other roles, and this difference was significant. The specialists identified more signs than other groups, with the
exception of the technical and team member roles. The team members identified more fences than other roles.

Significant effects of both unit and presentation order were shown. Presentation order shows significant correlation with the number of components and the number of buildings.

**Overview**

The aim of this experiment was to investigate whether role, previous training and instruction had effect on the ability of participants to deconstruct real images for both rural and urban environments.

The test images used in this experiment were panoramic images of real scenes containing a mixture of simple and more complex components. This is in contrast to some of the literature, where the test images used were of simplistic scenes, often specifically designed to elicit component information, for example Mandler and Johnson (1976).

Four of the ten test images contained junctions, whilst the remainder were taken along single roads. Seven of the test images were taken within the rural environment used for experiment one. Two of the urban images were taken from the urban environment used for experiment two, and the remaining image was a general urban scene taken in a local town.

In the instructions given to the participants prior to each exposure to the images, they were either asked to identify any prominent features or landmarks within the scene or asked to look for specific feature types within the scene. An effect of these instructions was apparent in six of the panoramas; panoramas 4, 5, 7 and 9 showed no effect of experimental condition.

In those images where the effect of instructions was significant for the number of contours, those asked to identify prominent features identified more contours than those asked to identify specific features. With the exception of panorama six, the majority of participants across both groups did not classify or recognise contours (less than 20% of participants) as relevant to their perception of the image. This may be due to relatively low resolution of the images, which meant that features further away within the image were less clear.
There is, therefore, some effect of instructions on the nature of the components identified by participants, however this is not significant across all component types for all images, and could, therefore, be concluded to be a minor effect.

**Effect of military specialisation**

There was a significant effect of military specialisation across the images, for a number of different components of the images. Of the test panoramic images, only panorama seven showed no effect of specialisation on the number and type of components identified. Panorama seven was a complex urban scene, with a large number of easily identifiable features.

In general the geographic specialists identified significantly more components overall than other specialisations tested in this experiment. This is unsurprising since their training involves the analysis and interpretation of imagery and maps. This group overall identified more components of more types than other specialisations.

The specialist and engineer groups identified significantly more detailed components on some of the panoramas tested. The group labelled “other” identified more particular points on two of the test panoramas. The infantry participants identified on some tests images significantly less components and details than other groups. However, it is likely this group do not get any specific training in analysing images or geographic information, other than those skills necessary for map reading and orientation.

Therefore, it is concluded to be possible that specific training does affect the analysis of images, however whether this analysis leads to improved spatial performance should be further investigated.

**Effect of role**

Within each group, each participant identified their normal working role, and the participants tested in this experiment ranged from team members with no specific training through to technical specialists.
In the entire test panorama set there were significant effects of role on some of the component types. Where these effects were identified, in general the team leader role appears to identify fewer components overall, and fewer details. In many of the panoramas, only the specialists or technical roles identified particular types of component, for example, only the specialists identified any signs in panorama three.

The reason for the team leader role identifying fewer components than the other roles is not immediately clear. At this level, military training has included some map reading tasks, therefore these participants would be expected to be familiar with the types of component identified in these panoramas. This role has responsibility for the team when undertaking activities.

That the specialists and technical roles identify more of some of the detailed components is to be expected, since their roles require them to be able to work with images and plan activities from these maps and images.

Conclusions

There is an effect of specific instructions on the nature of the components identified by participants, however this is not significant across all component types for all images, and could, therefore, be concluded to be a minor effect.

The geographic specialists identify more components than other specialisations.

Team leaders appear to identify fewer components and details than other roles.
Overview

The overall aim of this research project was to investigate the contribution of GIS and imagery toolsets to the acquisition of environmental knowledge by military participants. The literature reviewed in chapter two presents an unclear picture, with variable results depending on the environment used, the participants and the metrics. The results obtained from this research programme reinforce the conclusion that the contribution of such systems to the acquisition of spatial knowledge is far from a simple matter.

Summary of results

Rural experiment

The participants self reported knowledge of the environment significantly improved over the course of the experiment, and there was a significant interaction between experimental grouping and time. The participants exposed to imagery and GIS improved their knowledge of the environment to a greater extent than the control group.

Recognition of the key points used as stimuli in the spatial tests improved over the course of the six days of the experiment: there was a significant effect of learning, and a significant effect of experimental condition, but the interaction between time and condition was not significant. Overall, the imagery group recognised more key points than the control group.

Within the variables measured during the spatial tests, only the error in estimated bearing showed a significant effect of the interaction between time and experimental condition. Overall, the errors from the imagery group were smaller than those of the control group, and in both groups there is a trend towards decreasing the error over time.
Each participant was asked to create or update a sketch map of the environment on days two, four and five. A significant effect of both time and experimental condition was observed in the number of landmarks produced: the imagery group identified significantly more landmarks on each of the days than the control group, and in both groups the number of landmarks created increased over the course of the experiment.

The errors in location of these landmarks were recorded as errors in distance and bearing from the true location. These errors were relatively large, although the imagery group produced smaller errors than the control group, however the error produced by the imagery group appeared to increase with time. The imagery group distance errors in location of landmarks decreased with time. There was little apparent change in the distance errors of the control group over time. The imagery group appear to produce larger distance errors than the control group.

A significant effect of the interaction between time and role was observed for the distance error in landmark location on the sketch maps. No other factors (previous visits or sense of direction) were observed to affect the results.

Principal components analysis elicited six factors. Using these regression factors, significant effects of experimental condition were observed on two of the factors.

Two of the four groups undertook spatial tests using imagery after the walk through the environment. However, the rate of recognition of the images was low (less than 50% in all cases) and further analysis of these results was not undertaken.

**Urban experiment**

A total of 136 participants took part in this experiment, and were divided (within their normal working groups) into six experimental categories. The experimental design was a cross over, with each group (excepting eight participants) experiencing the control condition (maps only) either in the first learning and test session or the second.
Pre test measurements conducted at a location familiar to the participants (their normal working environment) showed some variability in performance at the measures used.

Urban spatial tests

Most of the experimental groups showed a decrease in the error in estimated bearing between test session one and two; the exception being the control-control group, however these effects were not shown to be significant. There was no significant effect of experimental condition identified for the bearing error for the first test, however the second test session did show a significant effect of experimental condition, in that the control-control group produced significantly greater errors than the control-imagery or imagery-imagery groups.

Most of the experimental groups showed a decrease in the error in estimated distance between test session one and two; the exception being the control-imagery and the imagery-imagery groups, however these effects were not shown to be significant. There was a significant effect of experimental condition identified for the distance error for the first test, in that the control-control group produced significantly greater errors than any of the other groups; however the second test session did not show a significant effect of experimental condition.

Components experiment

The results obtained showed a significant effect of role on the number of components identified. No significant effect of condition or the interaction between condition and role was identified. It was observed that the team leader role appeared to identify fewer components than the other categories. The specialist and the technical roles, particularly those in the specific group, identified more components in the urban image than other roles. The team leader role identified fewer components than the other roles.

The results showed a significant effect of specialisation, but no significant effect of experimental condition (specific instructions) or the interaction between
condition and specialisation was identified. The geographic specialists identified more components in all categories than other specialisations and this difference was significant; specialists and engineers identified more components than the other group.

Significant effects of specialisation were identified on a number of component types. Significant effects of role were identified for the number of road features and the number of contours identified. The number of buildings identified showed a significant interaction between experimental condition and role. The number of road features and the number of contours identified showed a significant interaction between experimental condition and specialisation. The number of road features, the number of contours, the number of buildings and the number of particular points all showed significant interactions between specialisation and role. The specialist role identified more road features, contours and trees than other roles, and the difference for road features was significant. Overall, all the roles identified more road features than any of the other categories of component. The team member role identified more trees than all other roles except the specialists Overall, all roles identified fewer buildings, signs, fences and particular points than other categories of component. The specialists identified more buildings than other roles, and this difference was significant. The specialists identified more signs than other groups, with the exception of the technical and team member roles. The team members identified more fences than other roles.

Significant effects of both unit and presentation order were shown. Presentation order shows significant correlation with the number of components and the number of buildings.

**Prediction of performance**

Pre test measurements were only available for the urban experiment, however most participants in both urban and rural experiments completed a questionnaire including a self assessment of their sense of direction. From the literature (Prestopnik and Roskos-Ewoldsen (2000)) gender and sense of direction are found to be predictors of performance.
The results obtained from both the rural and urban experiments show no overall effect of sense of direction on the performance of the participants in the spatial tests.

Within the urban experiments, the only significant correlations between pretest measurements and spatial tests occurred with the number of landmarks created on the sketch map of the familiar environment. This measure correlated significantly with some spatial tests and many of the variables derived from the sketch maps of the new urban environment. It is therefore proposed that the number of landmarks on a sketch map of a familiar area is one measure predicting learning and performance in a new environment.

**Principal component analysis**

Only one of the previous research papers reviewed conducted factor analysis on their results (Allen et al (1996)), and this research identified five factors: a spatial ability factor, a spatial sequential memory, a spatial perspective latency and topological knowledge and Euclidean direction knowledge from a battery of spatial ability tests and environmental tests.

Principal components analysis was conducted on both the urban and rural experiments, the rural experiment elicited six factors and the urban experiment five factors. From these results, it is not possible to derive any factors formed from spatial ability alone, as this was not specifically tested although this is implicit in the measures analysed. In the rural environment the six factors are: a Euclidean distance factor, a bearing error and sketch map landmark location error factor, a landmark knowledge factor, a bearing and Euclidean distance error factor and a final bearing factor.

In the urban environment the factors elicited are: sketch map number of features and the average distance error factor, distance errors in location of sketch maps landmarks factor, bearing errors in location of sketch maps landmarks and the number of landmarks for both sketch maps factor, number of nodes on sketch maps factor and the bearing error in location of sketch map landmarks and distance error in sketch map landmarks factor.
Both rural and urban analyses identify factors in common with Allen et al., in that Euclidean distance factors are elicited. The rural experiment also elicited a factor for the number of landmarks which could relate to the topographical factor observed by Allen et al. In addition to these factors, this research has identified factors related specifically to the accuracy of landmark location on sketch maps.

**Toolset**

In contrast with many of the virtual environments observed in previous research, the toolset available to the participants in these experiments was more complex, although it did not allow either full or incomplete immersion into the environment. A number of tools were collated together to allow participants to choose the information source appropriate to their tasks at any particular time. The information sources available to the participants were GIS (with mapping and imagery), panoramic images, still images and simple 3-Dimensional models.

The aim of this research was not to capture usability information for this particular toolset, although it was apparent from the rural experiment that familiarity with the toolset led to increased confidence and usage, which was less apparent in the urban experiments.

Some questions were raised concerning fidelity and resolution of the images, and these points should be further investigated.

It is considered that the GIS and imagery toolset used here is a simplified virtual environment, and as such it has much in common with the types of toolsets used in previous research. Much of the available literature has used video, slide presentations as well as simplistic virtual reality systems as aids to learning about an environment. This toolset combined a number of approaches, and updated the simple slide presentation to a series of linked panoramic images that allowed participants to “walk” along routes through the environment.

In general, there appeared to be a minor effect of using the GIS and imagery toolset, in that participants acquired more general knowledge about the environment and that this acquisition was faster that those participants learning
about an environment using maps. However, from the spatial tests used, there was no difference in the accuracy of location of landmarks.

The rural environment used in this research was large and complex, and as such does not provide direct comparison with the environments used in the literature. Many of the previous research studies used buildings, rooms or small sections of towns or campus as test environments, and these compare better with the urban environment used in experiment two.

In the literature reviewed for this study, there were no large rural environments used, so this study provides some useful insight into the application of some of the theories from urban environments to the rural.

In the rural environment, participants were able to access the tools available to them at will, and could spend as long as dictated by their other activities as they wished in so doing. In the urban environment, the learning process was constrained to two sessions each lasting approximately 45 minutes. Both learning strategies are deemed appropriate for considering the practicality of such tools, since typical military tasks will involve some longer term activities together with some shorter notice rapid tasks. The urban learning strategy bears most resemblance to the published literature, since many research articles constrained the learning time available to participants.

**Metrics**

The metrics used for capturing spatial knowledge about the environment are common to much of the literature. Most studies reviewed used some combination of Euclidean distance estimation, pointing tasks (relative or absolute bearings) and sketch maps.

Much of the literature refers to the individual variability in performance and the large errors produced by distance and bearing estimation tasks, and both the rural and urban confirmed this considerable variability.
Experimental results

The following sections in this chapter discuss the results from the individual experiments in the light of the published literature and in the light of the questions posed in the introduction.

Rural experiments

The rural environment used in this study was both large and complex; there were a number of available landmarks (buildings, farms, prominent geographical features) however these were necessarily more subtle and spread out than those that might be found in an urban environment. There were features however available to the participants to orient themselves with respect to the landscape, for example the environment was bordered almost completely on the southern edge by the sea, and this did give participants both a visual and audio cue as to their direction of travel in the environment.

There was considerable evidence that the participants acquired some spatial knowledge about the area during the six days of this experiment. This knowledge was acquired through both direct navigation and access to the appropriate toolset for the experimental condition. The recognition of the landmarks increased across the course of the experiment, however this is in contradiction to the findings of Gärling et al (1981) who found that acquisition of landmarks was rapid, in this experiment acquisition of the test set of landmarks took several days. It is likely that this delay in complete acquisition is due to two factors, firstly the size of the environment to be learned and secondly the nature of the navigation through the environment. In Gärling et al's experiment, participants were expected to learn a single route of approximately 10 minutes driving duration. In this experiment, other training activities took the participants on a total of twelve separate, but overlapping, routes through the environment over the course of the experiment. The learning activities undertaken by the participants were directly related to learning the routes for each day, and therefore acquisition of all the landmarks was delayed. This is an example of the training tasks forcing a segmented approach to learning the environment. This
would tend to support the Moar and Carleton (1983) findings that new elements of the environment are coded with respect to earlier learned elements.

Ruddle et al (1999) used maps as aids to navigating through the virtual environments, and in part this approach was applied to these experiments. Participants using the imagery toolset had available to them different scales of mapping on the GIS as well as the paper maps, which they were required to use for their unrelated training tasks.

There was a significant learning effect observed in the sketch map data for the imagery group, in that all three measures showed significant increases (i.e., number of landmarks, number of nodes and number of features).

The team members did show significant effect of condition on the increase of accuracy of bearing error across the days. The imagery condition shows significantly smaller errors than the control group, but both groups show a trend towards improvement in accuracy across the six days.

In contrast to Wilson (1997) there appears to be some transfer of knowledge from the virtual to the real environment, however the combination of navigation and map or virtual environment learning appears to lead to the acquisition of an imperfect and inaccurate survey knowledge. This concurs with Richardson et al (1999) who concluded for complex environments, participants showed poor accuracy compared to navigational learning.

The landmarks used as test stimuli in this experiment were chosen to be prominent markers, buildings or highly distinctive road junctions (for example, a five way junction adjacent to a cattle crush). Of the fifteen landmarks available for testing, only a subset was used for each participant, since there was a need to ensure that the landmark was out of sight at the test location. Landmarks were identified on both the maps and the imagery toolset, and panoramic images were available (and annotated) for each of the landmarks, as well as other points and segments of the routes. However, given the nature of the rural environment which was sparse, the landmarks available could be easily confused (for example, one hill top could easily resemble another). There were relatively few buildings in the environment, and most of these were used as landmarks for test,
however some of these were well hidden, and until the training tasks took the participants past these points specifically (which did happen for all points at some stage during the six days), the participants were unlikely to learn these.

This is likely to be an important finding for the practical use of such tools: anecdotal evidence from the trials suggests that the imagery was useful for discovering the type of environment (eg hilly, boggy, streams or crops), but has not been demonstrated so far as useful for accurately locating the participant once in the environment.

Both the number of landmarks recognised in the spatial tests and the number of landmarks identifiable on the sketch maps showed significant learning effects across the course of the experiment. By day three of the experiment, seven of the fifteen test landmarks were recognised in greater than 80% of the presentations. This did not improve significantly over the remainder of the experiment, suggesting a plateau effect.

From Jansen-Osmann (2002), landmarks play an important role in the acquisition of knowledge, and the less distinctive natures of some of the rural landmarks may have degraded some of the learning for the participants in this series of experiments.

The available literature does not in general compare the rates of acquisition of knowledge for maps, navigation and virtual environments, particularly over such long timescales as were used in this experiment.

There is no confirmatory evidence of accelerated learning of an environment using the imagery toolset from the results obtained. However there was considerable individual variation in the responses to the tests, and it is likely that this masks any effect of the experimental condition.

There were no significant differences identified between the groups in the knowledge of the key points on the spatial tests. However, the number of landmarks created by each group on the sketch map tests were significantly different, and there is an indication that the imagery group increased the number of landmarks over the days tested faster than the control group. It must be stated that this is a tenuous indication of rate of knowledge acquisition, and
subject to a number of confounding factors. The four groups tested, although covering all twelve routes over the course of the six days, did cover them in different orders, and therefore their navigation experience is likely to have differed across the days. This cannot easily be accounted for and therefore any differences highlighted here should be treated with caution.

For military tasks, as with many everyday tasks, a combination of route and survey knowledge is required to achieve the activities required. For the training tasks, although not part of this research, the participants were required to find their way along a pre-determined route, conducting activities along the way. These activities could be responses to events, searching for items or merely observing and recording details about the environment. This is in common with everyday tasks such as driving to work: if the road is blocked by a fallen tree or accident, then an alternative route must be identified and used. There may be the need to carry out tasks along the route, for example stop at a post box to post a letter. This may require planning to identify a post box along the route where it is safe to stop.

All of these tasks require both route knowledge (a knowledge of distances and orientation along routes, and details of the landmarks along the route) and survey knowledge (a birds eye view of the environment, identifying spatial relationships between elements, generalising beyond learned routes).

The group and team leaders have maps on the task with them to aid wayfinding and activities, although the team members do not carry maps or other information sources with them routinely.

There is evidence from the results obtained from the rural experiment that the participants were acquiring some level of survey knowledge, in that they were able to some degree to create sketch maps of the environment. The level of route knowledge obtained was more difficult to establish, although there is some indication that landmarks were identifiable particularly after navigation along routes that had included these. Whether the increase in landmark recognition was due to direct experience through navigation or to the fact that planning for that activity had required the participants to learn about the
landmarks is not clear from these data. This is a major confounding factor in this experiment.

The accuracy of the distance and bearing estimations, although improving through the experiment, did not significantly prove superiority of either source of learning. The results were widely variable across individuals and days of test, and therefore there is little direct evidence to conclude that participants were acquiring either survey or route knowledge accurately. In view of this wide variability in individual performance, it is not deemed appropriate to attempt to either validate existing models or create a new model of the learning process undertaken by participants during this experiment.

In much of the previous research, the spatial tests used resulted in reasonably accurate results (for example bearing errors of 45° or less). The accuracy observed in these experiments was variable over the course of the six days, but within the limits of that seen in the literature: table 8-1 summarises the actual errors in estimated bearing observed by day.

**Table 8-1: Mean bearing errors by group across the days of the rural experiment**

<table>
<thead>
<tr>
<th></th>
<th>Control group</th>
<th>Imagery group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean error in estimated bearing (degrees)</td>
<td>Mean error in estimated bearing (degrees)</td>
<td></td>
</tr>
<tr>
<td>Day 1</td>
<td>31.14</td>
<td>30.0</td>
</tr>
<tr>
<td>Day 2</td>
<td>34.13</td>
<td>36.92</td>
</tr>
<tr>
<td>Day 3</td>
<td>33.09</td>
<td>49.82</td>
</tr>
<tr>
<td>Day 4</td>
<td>42.87</td>
<td>52.86</td>
</tr>
<tr>
<td>Day 5</td>
<td>32.63</td>
<td>26.60</td>
</tr>
<tr>
<td>Day 6</td>
<td>38.09</td>
<td>35.59</td>
</tr>
</tbody>
</table>
There was considerable individual variation in the bearing and distance errors observed during the trials. In many cases the participants were almost 180° in error on estimating the bearing of a location, and several kilometres in error in Euclidean distance estimation. This contrasted with some participants who were within 5-10° of the true bearing and within 0.05 km of the true Euclidean distance. Even within individuals, their performance was found to vary considerably across the test sessions. This inter and intra individual variability made discerning any effect of the imagery toolset on the learning ability difficult. This supports Wilson et al (1997) who concluded that any effects of using virtual environments are small and difficult to detect.

The sketch map data appear to support Goldin and Thorndyke (1982) in that the virtual environment appears to aid participants in landmark recall.

The use of sketch maps to characterise the model of the environment created by each participant is well established in the literature, and the analysis techniques established by Young (1999) proved to be useful in this environment. Although unpopular to complete, the sketch maps were the most sensitive measure for identifying any effects of learning or condition on the participants’ cognitive models of the environment.

There was insufficient evidence of any effect of sense of direction on the performance of the participants in any of the spatial tests.  

There was a trend towards improvement in self assessed knowledge of the environment across the days of the experiment, although this was not significant for the control group. There were no significant differences between the two experimental groups in their self assessed knowledge on any of the individual days, however the imagery group did show a significant improvement in their environment knowledge between day 6 and day 1.  

The participants would have been expected to have acquired considerable route knowledge over the course of the 6 days of the experiment, since they were walking around 15km per day, within a relatively confined area. The routes that they were following covered the complete area under test (since the four groups were separated by distance during each of the walks) and overlapped.
Therefore it is surprising that their perceived knowledge of the area did not improve further. The nature of this self assessed knowledge was not investigated further at the time of the experiment, and in future experiments of this type this should be undertaken. It is possible that the participants were assessing good and very good knowledge to include knowledge of all the roads, paths and landmarks, covering the entire area. It is possible that the participants felt they had good knowledge of parts of the environment but not the whole, and therefore a single score of assessed knowledge was worse. Future research should attempt to determine whether the knowledge of an area of this size is inconsistent or at a coherent level across the entire area.

A significant effect of the interaction between time and role was observed, however the small number of participants in the group leader role made the precise nature of the interactions difficult to determine. This effect of role, and the implications of the training and experience associated with role, is not precisely covered in the literature accessed. This should be further investigated to determine the effect of specific training and experience on the applicability of GIS and imagery toolsets to the military user.

Urban experiments

The urban environment used for these trials was considerably smaller than the rural environment, but was enclosed on all sides by major roads. Within the environment, there were a number of features typically expected in a small urban community: convenience stores, housing, some small office blocks and a small industrial type estate. There were some distinctive features, which were considered easily identifiable, for example some larger road junctions with visible buildings of particular shapes. The specified route that participants walked around this route was approximately one mile in length and covered a large proportion of the environment and the landmarks.

Much of the previous research in this field considers the urban environment, and the landmarks within the urban environment are likely to be more in number and possibly more distinctive than those in a rural environment, for example, an unusual shape of building is possibly more readily identifiable than an unusual tree within a copse.
Much of the literature available used more simple urban environments than that used for this experiment, however the aim of this particular experiment was to investigate whether this type of toolset had utility for a realistic environment. Overall, the literature is contradictory when considering whether virtual environments do affect learning of real environments. Richardson et al (1999) concluded that when time of exposure to the learning material was equivalent, then there was no difference in the level of knowledge acquired from maps and navigation in the virtual environment. Goldin and Thorndyke (1982) using film as the virtual environment showed that the film group were more accurate than direct navigation at recall of landmarks and landmark sequencing. Wilson et al (1997) showed some transfer of learning in the virtual environment being transferred to the real environment. Rossano and Moak (1998) showed no difference between map learning and learning from virtual environments. However, Wilson (1999) showed that there was little or no transfer from virtual to real environments.

For this experiment, participants were given two introduction sessions to the urban environment, once at pre-test session between one and seven days prior to the test and the second immediately prior to the test. Each session was approximately 45 minutes long, and consisted of an introduction by the researcher using the appropriate toolset, and highlighting a specified route and the landmarks to be seen from that route, and then a free learning session. This compares well with the methods used in the literature, in that learning sessions were comparable (although some studies used recall performance to determine the end of the learning session, time did not permit that method to be used in this experiment).

The use of the toolset by the participants was variable across the groups, some groups actively used the GIS and imagery when available, and others were more reluctant. Where reluctance was shown then the researcher was available to use the system at the request of the group (for example, showing particular images on demand, zooming in and out on maps and imagery). This meant that there was a mix of active and passive learning both between groups and within groups. In general when participants were using maps, there were maps
available for each pair of participants to use and their team and group leaders strongly encouraged the learning of the environment.

From the number of key points (landmarks used in the spatial pointing and distance estimation tasks) recognised by the participants, the participants appeared to have learned the landmarks within this environment, at least to the point where the key point is recognised, if not to accurate location of the key point.

There were no significant differences between the groups in the accuracy of the pointing or distance estimation, showing that there was no identifiable effect of the experimental condition on acquiring accurate information in this experimental design.

In general the landmarks used in this experiment were well recognised across all the groups, and there was little identifiable difference between the sessions in the recognition rate. A confounding factor in this recognition is that some of the landmarks used were those that might be found in any area of this type, for example convenience stores. Those that were less well recognised, for example key point six which is a distinctive road junction, were landmarks that were specifically representative of this environment.

The number of landmarks identified and located on the sketch map data did show an effect of experimental condition. Of all the groups tested, only those presented with the imagery condition first appeared to show little or no improvement between the sessions. The group presented with maps first and imagery + instruction second did identify a significantly greater number of landmarks on their first map. The reason for this difference cannot readily be explained from the data, these participants were from the same specialisation and base location as other participants within the experiment. It is possible that group leadership for these participants was more influential in guiding the learning process for this group than for others, but this cannot be proven from the data available at this point.

In general, the participants did show (with the exception of the imagery-control group) an increase in the number of landmarks identified on the sketch
maps between the first and second sessions. This shows that there was a learning effect. It would appear that the group presented with imagery+instruction produced more landmarks on their second map than any of the other groups (this difference was significant for the control-control group and the imagery-control groups). This supports the conclusion that specific instruction does have an effect on the learning process.

The landmarks identified on the sketch maps were the obvious landmarks expected: the convenience stores, the office block where the experiment took place, the leisure centre etc. However, a number of the participants failed to provide sufficient landmarks for all the location data to be accurately estimated.

The evidence from the sketch maps suggests that the participants were acquiring some level of survey knowledge. This experiment did not use landmark sequence recall to test route knowledge, however on completion of the route, participants did appear to improve their knowledge of the landmarks suggesting that direct experience did lead to some route knowledge acquisition.

There is some evidence from the data that those participants provided with imagery+instruction do acquire more knowledge of the landmarks within the environment, however, there is no evidence that experimental condition changes the accuracy of the landmark location estimates.

Even on the pre-test sketch maps of the location familiar to them (their normal place of work) the errors were large (mean bearing error 54°, median 46°; mean distance error 0.72km, median distance error 0.57km).

Within the pointing tests and distance estimation at their normal place of work (somewhere that should be familiar to all participants), the performance of the participants was variable (for example, mean bearing error on the first landmark 126°, median 77.5°). This would tend to suggest that the participants either lacked knowledge about an area that was considered to be familiar or lacked the ability to locate landmarks within that area. All the participants were able to create sketch maps of their familiar areas, and therefore could be considered to be familiar with the area. In some cases, the familiar environment was larger than the test environment, but this was not always the case. It must,
therefore, be concluded that the performance of the participants in the spatial tests was variable.

Unsurprisingly, this large variability in performance was also observed in the test data. For the test data, the errors were converted to percentages of the actual distance, and average distance error across all the groups was 46%, (median 39%) and average bearing error was 40° (median 38°), so performance appears to be improved in the new environment. The reason for this improvement in performance cannot be definitively identified from the data observed, but it would appear that there is considerable variability both between participants, and within participants over the test sequences measured.

Further analysis of the effects of the experimental conditions was conducted using performance in the familiar environment tests to divide the data set. The two data sets analysed included firstly those participants estimating the bearing of a landmark to less than 90° error, and secondly those participants estimating the bearing of landmarks to greater than 90° error. There were no significant effects of experimental condition found in either of these cases.

From the data observed, it would appear that due to high variability of performance, any effect of experimental condition was small and hidden. This concurs with Wilson et al (1997) who concluded that large variation in individual performance in their experiments could mask any effect of using virtual environments as a learning tool.

From the evidence that the participants were able to construct sketch maps of the new environment, it is concluded that the time available for learning the environment was sufficient for some degree of spatial knowledge acquisition to have occurred.

The effects observed in this experiment are in contrast with those identified by Barsam and Simutis (1984), who concluded that participants with high spatial ability scores actively engaging with a virtual environment significantly enhanced their performance. Although no direct measures of spatial ability were used in this experiment, (although some authors concluded that pointing performance in a familiar environment was a good predictor of spatial ability), those participants
scoring well on the pre-test familiar environment did not show any effect of experimental condition on the new environment tests.

These results also contradicted Witmer and Sodowski (1998) who showed that distance estimation errors were doubled when participants used a virtual environment, however in their experiment, Witmer and Sodowski also required their participants to estimate within the virtual environment, rather than the real environment. Rossano and Moak (1998) showed no differences between learning from maps and virtual environments.

However, in much of the literature available to this study, the environments used were small, and the errors observed were small. Where the environments were larger or more complex, then some studies did report larger errors. In particular, Wilson et al (1997) who reported that individual variability masked small effects of the experimental conditions.

**Comparison of results from the rural and urban experiments**

The two environments used for these experiments had a number of important differences, obviously one was urban and the other rural, but in addition, the rural environment had landmarks that were highly specific to this environment. For example, the names of visible hilltops and one of the points on the cliff overlooking the sea were all highly distinctive and could not be confused with landmarks in other areas. This was not the case with the urban environment, where only the road names were particularly distinctive. Convenience stores, office buildings and small industrial estate buildings could occur in other similar environments and could be predicted to be within this environment. Therefore, recognition of key points in the rural environment is a real effect of learning about that particular environment, whereas with some of the landmarks on the urban environment could be the results of deducing their existence rather than learning.

The rural experiment was a longitudinal study over six days, whereas the urban experiment was a short test sequence lasting approximately three hours.
In the rural environment the use of the imagery toolset was found to significantly decrease the errors in estimated bearing to key points, however the effects were much less clear in the urban environment.

There was evidence of learning the environment from the rural experiment, and some limited evidence that the GIS and imagery toolset supported this learning. Recognition of the unfamiliar landmarks in the rural environment increased over the course of the experiment, and the number of landmarks identified on the sketch maps also increased over the course of the six days. There was also evidence of learning in the urban environment, but the evidence was less clear than in the rural environment.

The level of error in pointing tasks was comparable in both experiments, but a high degree of individual variability was observed in all participants. This was both a variability within responses from a single individual and between individuals. It is concluded that this high degree of variability masked any effect of the experimental conditions in both environments.

In the rural experiment, the participants were mostly from the same background, (although some participants were new to their groups), in contrast, the participants in the urban environment came from a number of backgrounds. The effect of previous training on performance is not covered in the literature available to date. However, it can be concluded that different groups within the military will have different training schemes and different experience, and it is highly likely that these will influence the performance of the individuals.

In both rural and urban environments, the sketch map tests proved to be a useful means of eliciting the spatial knowledge acquired by the participants, and in both environments the number of landmarks shows significant effects of both experimental condition and of learning over time.

In both the rural and urban experiments, the methods used by participants to learn the environments varied. Some of those participants learning using the virtual environment (GIS and Imagery) actively engaged in using the tools, whilst others passively observed. Within the population of participants using maps to learn the environments, some participant groups were actively encouraged to
learn the landmarks by rote, and others listened passively to presentations. The literature is contradictory on whether this active or passive learning should have an effect, Kinnear and Wood (1987) showed that active engagement in the learning process increased learning and therefore performance, whilst Wilson et al (1997) showed no such effect.

**Image components**

The test images used in this experiment were panoramic images of real scenes containing a mixture of simple and more complex components. This is in contrast to some of the literature, where the test images used were of simplistic scenes, often specifically designed to elicit component information, for example Mandler and Johnson (1976).

For those six images where a significant effect of condition was found, only panorama three showed this effect on the total number of components identified. For the remaining five images, the effect was noticeable in the number of component types.

In those images where the effect of instructions was significant for the number of contours, those asked to identify prominent features identified more contours than those asked to identify specific features. With the exception of panorama six, the majority of participants across both groups did not classify or recognise contours (less than 20% of participants) as relevant to their perception of the image. This may be due to relatively low resolution of the images, which meant that features further away within the image were less clear.

There is, therefore, some effect of instructions on the nature of the components identified by participants, however this is not significant across all component types for all images, and could, therefore, be concluded to be a minor effect.

*Effect of military specialisation*

There was a significant effect of military specialisation across the images, for a number of different components of the images. There were differences in the types of component identified by each of the groups. In general the geographic specialists identified significantly more components overall than other
specialisations tested in this experiment. This is unsurprising since their training involves the analysis and interpretation of imagery and maps. This group overall identified more components of more types than other specialisations.

The specialist and engineer groups identified significantly more detailed components on some of the panoramas tested. The group labelled “other” identified more particular points on two of the test panoramas. The infantry participants identified on some tests images significantly less components and details than other groups. However, it is likely this group do not get any specific training in analysing images or geographic information, other than those skills necessary for map reading and orientation.

Therefore, it is concluded to be possible that specific training does affect the analysis of images, however whether this analysis leads to improved spatial performance should be further investigated.

Effect of role

Within each group, each participant identified their normal working role, and the participants tested in this experiment ranged from team members with no specific training through to technical specialists.

The reason for the team leader role identifying fewer components than the other roles is not immediately clear. At this level, military training has included some map reading tasks, therefore these participants would be expected to be familiar with the types of component identified in these panoramas. This role has responsibility for the team when undertaking activities.

That the specialists and technical roles identify more of some of the detailed components is to be expected, since their roles require them to be able to work with images and plan activities from these maps and images.

Confounding factors

A number of confounding factors were observed in these experiments, although attempts were made to control some of these, some remained outside the control of the researcher. In the rural environment, the training tasks took precedence over these experiments, and therefore the participants undertook
their own routes through the environment. These routes were not predictable, and not all members of a group would follow precisely the same route. Whilst the differences in route followed may be small, it is possible that the different perception of the environment may have affected the acquisition of knowledge in this environment. Within the urban environment, the route followed was controlled, and the groups were led on foot through the environment along a pre-defined route, stopping at the same locations for the pointing and distance estimation tasks.

There was a perceptible lack of engagement from the participants for some of the measures used, particularly the sketch maps, although this was group dependent. Although a valuable measure of knowledge acquisition, particularly over the six days of the rural experiment, these maps did take time to complete. To overcome this, in the rural experiment, participants were encouraged to create the maps initially in pencil, and thereafter to update them rather than create new maps on each day. In addition, maps were only created on three of the experimental days rather than all six. This appeared to be more acceptable to the participants, and did produce valuable data.

Participants from different military backgrounds will have different training and experience, and it is not possible to control for these within the experimental process. This does have an impact on the acquisition of spatial knowledge, as proven in the urban experiments.

Initial questions

The results from this research do not conclusively support the statement that GIS and imagery are "a better way" of learning an environment than using maps. From both the literature and this research, maps do provide a valuable and succinct source of information. It would appear that use of imagery toolsets does provide participants with more confidence and more knowledge about the environment, but that this information is generally no more accurate that the knowledge acquired from maps. Therefore the use of imagery and GIS is a useful additional toolset, but not a replacement for the maps.
The use of GIS and imagery appear to support the improved learning of the landmark information, as tested by recall tests, however the accuracy of placement of those landmarks on sketch maps, and with some minor exceptions, the accuracy of locating relative position of landmarks is no more accurate with the use of GIS and imagery than merely using maps.

From the research reported in this thesis, it would appear that in both rural and urban environments, participants are acquiring some degree of survey and route knowledge, however this appears to be an imperfect representation of the environment, and participants are not always able to accurately manipulated their information.

The participants had different strategies for using the imagery toolset: on occasions, one member of the group would be identified as the user, and this member would create the views for the remainder of the group according to the tasks for the day. At other times, for one set of users, the remaining participants did actively engage with the toolset to learn about the environment.

There is definitely an effect of role and specialisation on the acquisition of spatial knowledge and the deconstruction of imagery. Geographic specialists unsurprisingly are able to identify more components within an image. Infantry participants appear to perform less well than participants from other backgrounds.
SUMMARY AND CONCLUSIONS

Summary

This thesis reports a series of experiments undertaken to answer a number of questions, principally whether the use of Geographic Information Systems (GIS) and imagery of a novel environment assists and accelerates learning of that environment for military personnel. The research aimed to investigate whether any effect of the GIS and imagery toolset was apparent in both rural and urban environments.

Previous research has principally concentrated on urban environments, although many of the environments considered have been small and simple. In general the literature was contradictory concerning the effects of using virtual environments (including films, slide shows and computer simulations), with some research suggesting a positive effect, and some research either showing no effect or a negative effect. Much of the previous research has used university or college students and staff as the participants. Therefore there was little conclusive evidence of the utility of such toolsets for military use in real urban and rural environments. It was decided that a series of experiments should be undertaken to further investigate the use of these toolsets in the military environment.

In each of the experiments described here, the participants were military personnel.

Initially an experiment within the rural environment was undertaken. This took place alongside a military training programme, and was a longitudinal study over six days. Participants were divided into two groups, those using maps (control) and those using the GIS and imagery toolsets (Imagery). Participants were given access to their learning materials at will, and as part of the training programme were tasked to undertake twelve walks through pre-determined routes throughout the environment. At a point along each route, participants
were asked to provide Euclidean distance estimation and estimated bearing to two key points. On three evenings, participants were asked to create or update sketch maps of the environment.

The experimental tools and information were found to be useful as tools for introducing the rural environment and planning activities within this environment. The imagery group showed smaller errors in the initial days of the experiment, and identified more landmarks on sketch maps than the control groups.

There was a general identifiable trend towards increased recognition of the rural key points used for pointing and distance estimation tasks over the course of the experiment across all groups.

There was a significant effect of time and experimental condition on the error in estimated bearing to rural key points: the imagery group showed significantly smaller errors. Both groups showed a significant decrease in error over the course of the experiment.

The imagery group identified significantly more landmarks on the last day of testing on the sketch map test. The imagery group showed significant differences between day two and day five for the number of landmarks, nodes and features identified. Using unannotated panoramic images for spatial knowledge tests failed to elicit usable data.

There is some evidence to suggest that the experimental groups have a slightly increased knowledge of the rural environment, but this knowledge is not more accurate than that of the control groups, i.e., the experimental groups know the names of more places, but cannot pinpoint them on a sketch map with any greater accuracy.

A second experiment was planned in part to continue investigation of the initial questions, and in part to overcome some of the confounding factors from the rural experiment. This second experiment took place in a small urban environment. Participants were assigned to one of the experimental conditions in their normal working groups, the experimental design was a cross-over, with three conditions: control (using maps only), imagery (using the GIS and imagery toolset) and Imagery+instruction (where participants using the GIS and imagery
toolset were instructed to identify particular points within the images). Each participant group were trained using the appropriate initial toolset, then taken on a walk around the urban environment. Pointing and distance estimation tasks were undertaken at two points during this walk. On completion of the walk, participants were asked to create a sketch map of the area. After the first test sequence, the participants were re-trained using the appropriate toolset for the second condition and the walkthrough and tests were repeated.

Considerable variability in performance was observed with the participants in the urban environment, even within an area familiar to them.

In the urban experiment, no overall effect of sense of direction on performance or learning was shown.

Principal components analysis of the data gathered in the urban environment elicited five factors; using the regression factors derived from the analysis showed significant effects of experimental condition on three of these factors.

All groups in the urban experiment identified more landmarks on the second test compared to the first test, however this effect was not shown to be significant. There were significant effects of condition on a number of the sketch map variables for each of the first and second test sessions.

The third experiment followed as a result of the findings in the first, rural, experiment that participants were not always able to identify images of points within the rural environment that they had visited. It was decided that further analysis of the components within a scene identified by participants, and the effect of background and experience on those components should be undertaken.

There is an effect of specific instructions on the nature of the components identified by participants, however this is not significant across all component types for all images, and could, therefore, be concluded to be a minor effect.

The geographic specialists identify more components than other specialisations. Team leaders appear to identify fewer components and details than other roles.
Conclusions

From both the literature and this research, maps do provide a valuable and succinct source of information. It would appear that use of imagery toolsets does provide participants with more confidence and more knowledge about the environment, but that this information is generally no more accurate than the knowledge acquired from maps.

The use of GIS and imagery appear to support the improved learning of the landmark information, as tested by recall, however the accuracy of placement of those landmarks on sketch maps, and with some minor exceptions, the accuracy of locating relative position of landmarks is no more accurate with the use of GIS and imagery than merely using maps.

Sketch maps proved to be a useful and sensitive means of capturing information about spatial knowledge acquisition by participants. In both rural and urban environments the number of landmarks created on the sketch maps shows significant effects of both experimental condition and of learning over time.

It is concluded that the effects of using a GIS and imagery toolset are small.

A high degree of variability in performance was observed both within and between participants.

There is definitely an effect of role and specialisation on the deconstruction of imagery. Geographic specialists unsurprisingly are able to identify more components within an image. Infantry participants appear to identify fewer components than participants from other backgrounds.

Recommendations

Some limited analysis has been undertaken within this research study to investigate the features within the image that aid recognition, but further work is required in this area. The reverse case should also be tested: ie does training with the imagery lead to recognition of the actual environment?

With a rural area, it is likely that images will be confused, as the potential landmarks available within the view are limited. Further work is essential to
understand this phenomenon, and to make recommendations for use of this type of toolset in the rural situation.

It is concluded to be possible that specific training does affect the analysis of images, however whether this analysis leads to improved spatial performance should be further investigated.


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ANNEX A
PARTICIPANT QUESTIONNAIRE

So that the research team can interpret the information we collect before, during and after this exercise, we will need some background information about you, your experience and your training.

The information on these sheets will be kept within the research team, and will not be passed to any other agency or made available to your unit. This information will be used for analysing the results of this study only and will be kept in secure storage.

Name.................................................................

What is your usual role in the team............................................

Have you worked with this group before yes / no*

Have you worked together as a group
   once / 2-5 times / 6-9 times / 10 or more times*

How long have you worked with this group?
   Less than one month / 2-5 months / more than 6 months

Age............

Total length of service ..................yrs

Have you completed training courses in rural environments? Yes / No*

If yes, was this: initial training / continuation training / both*

When was your last course in rural environment? ..................month/year

Have you trained at this training area before Yes / No*

If yes, when was your last visit?.................................
How often have you trained at this environment?
once / 2-5 times / more than 5 times*

Do you use a computer at work? Yes / No

If yes, do you use a computer
less than once per week / once per week / daily

Do you have a computer at home? Yes / No

If yes, do you use a computer
less than once per week / once per week / daily

If yes, do you use the internet? Yes / No

Have you completed any training courses for IT? Yes / No

If yes, please list the courses completed and when.

Is your sense of direction:

Very Good / Good / Average / Poor / Very poor*

Thank you for your time in completing this questionnaire.
ANNEX B

RURAL EXPERIMENT:

SUPPLEMENTARY DATA
Use of key points by day for the rural experiments

Table B-1: Distribution of key points by day and test location

<table>
<thead>
<tr>
<th>Key Point</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Point</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>2nd Point</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Test location 1</td>
<td>1st Point</td>
<td>6</td>
<td>5</td>
<td>12</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
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<tr>
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<td>4</td>
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<td>5</td>
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<tr>
<td></td>
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<td>6</td>
<td>6</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Test location 2</td>
<td>1st Point</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>2nd Point</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Test location 1</td>
<td>1st Point</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
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<tr>
<td></td>
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<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Test location 2</td>
<td>1st Point</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2nd Point</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
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<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2nd Point</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Total: 46 46 46 46 46 46 46 46 46 46 46 46 46 46 46 46 46 46 46 46 46 46 46 46 46 46 46 46
Table B-2 – Number of presentations of each of test panoramic photographs across all participants by day

<table>
<thead>
<tr>
<th>Test photo ID</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Contl</td>
<td>Imag</td>
<td>Contl</td>
<td>Imag</td>
</tr>
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<td></td>
<td>4</td>
</tr>
<tr>
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<td></td>
<td></td>
<td>4</td>
<td></td>
<td>4</td>
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<tr>
<td>Panorama 3</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Panorama 4</td>
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<td></td>
</tr>
<tr>
<td>Panorama 5</td>
<td>7</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panorama 6</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Panorama 7</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Panorama 8</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
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<td>Panorama 9</td>
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</tr>
<tr>
<td>Panorama 10</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Panorama 11</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Panorama 12</td>
<td></td>
<td></td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Panorama 13</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Panorama 14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panorama 15</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Panorama 16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panorama 17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panorama 18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number</td>
<td>9</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
</tbody>
</table>
Table B3: Self assessed knowledge of the environment across all participants by day of the experiment

<table>
<thead>
<tr>
<th></th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>%</td>
<td>No</td>
<td>%</td>
<td>No</td>
<td>%</td>
</tr>
<tr>
<td>Very Good</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>2</td>
<td>4.3</td>
<td>1</td>
<td>2.2</td>
<td>5</td>
<td>10.9</td>
</tr>
<tr>
<td>Adequate</td>
<td>13</td>
<td>28.3</td>
<td>10</td>
<td>21.7</td>
<td>18</td>
<td>39.1</td>
</tr>
<tr>
<td>Poor</td>
<td>15</td>
<td>32.6</td>
<td>12</td>
<td>26.1</td>
<td>15</td>
<td>32.6</td>
</tr>
<tr>
<td>Very Poor</td>
<td>4</td>
<td>8.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>34</td>
<td>73.9</td>
<td>23</td>
<td>50</td>
<td>38</td>
<td>82.6</td>
</tr>
</tbody>
</table>

The information from these tables is summarised in the graph at figure B-1.
Figure B-1: Graphical representation of the self assessed knowledge of the environment across all participants by day of the experiment.

The graph at figure B-1 shows the self assessed knowledge of the environment for all participants for each day of the exercise. There is a slight discernable trend to show an improvement across the days, in that very poor assessments were recorded on day one and that a very good assessment was recorded on day six. Good assessments increase across the days from less than 3 on day one to 9 participants on day six.
Table B-4: Knowledge of key points across all participants by day and key point identification

<table>
<thead>
<tr>
<th>Key point number</th>
<th>Day 1 % known</th>
<th>Day 2 % known</th>
<th>Day 3 % known</th>
<th>Day 4 % known</th>
<th>Day 5 % known</th>
<th>Day 6 % known</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16.7</td>
<td>57.1</td>
<td>80.0</td>
<td>66.7</td>
<td>100.0</td>
<td>81.8</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
<td>23.5</td>
<td>42.9</td>
<td>75.0</td>
<td>50.0</td>
<td>76.5</td>
</tr>
<tr>
<td>3</td>
<td>54.5</td>
<td>70.6</td>
<td>77.8</td>
<td>91.7</td>
<td>83.3</td>
<td>60.0</td>
</tr>
<tr>
<td>4</td>
<td>94.1</td>
<td>100.0</td>
<td>75.0</td>
<td>93.8</td>
<td>75.0</td>
<td>100.0</td>
</tr>
<tr>
<td>5</td>
<td>47.8</td>
<td>50.0</td>
<td>63.6</td>
<td>82.6</td>
<td>86.7</td>
<td>70.8</td>
</tr>
<tr>
<td>6</td>
<td>76.2</td>
<td>95.7</td>
<td>100.0</td>
<td>91.3</td>
<td>94.4</td>
<td>91.7</td>
</tr>
<tr>
<td>7</td>
<td>8.3</td>
<td>83.3</td>
<td>91.7</td>
<td>100.0</td>
<td>75.0</td>
<td>90.9</td>
</tr>
<tr>
<td>8</td>
<td>16.7</td>
<td>60.0</td>
<td>50.0</td>
<td>83.3</td>
<td>44.4</td>
<td>63.6</td>
</tr>
<tr>
<td>9</td>
<td>50.0</td>
<td>16.7</td>
<td>36.4</td>
<td>26.7</td>
<td>83.3</td>
<td>66.7</td>
</tr>
<tr>
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<td>83.3</td>
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</tr>
<tr>
<td>11</td>
<td>54.5</td>
<td>37.5</td>
<td>66.7</td>
<td>50.0</td>
<td>86.7</td>
<td>58.3</td>
</tr>
<tr>
<td>12</td>
<td>16.7</td>
<td>54.5</td>
<td>38.1</td>
<td>50.0</td>
<td>66.7</td>
<td>45.5</td>
</tr>
<tr>
<td>13</td>
<td>36.4</td>
<td>29.4</td>
<td>64.7</td>
<td>63.6</td>
<td>75.0</td>
<td>61.1</td>
</tr>
<tr>
<td>14</td>
<td>44.4</td>
<td>33.3</td>
<td>75.0</td>
<td>66.7</td>
<td>83.3</td>
<td>72.7</td>
</tr>
<tr>
<td>15</td>
<td>83.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>83.3</td>
</tr>
</tbody>
</table>
Table B-4 and Figure B-2 show a general trend towards increased recognition of the key points over the days of the experiment, which is to be expected from previous research. In particular, Key Points 1, 7, 8, 12, 13 and 14 show an increasing trend from a low recognition rate on day one to a higher rate on day three and six. However, other key points in this set do not show any identifiable trend. Key points 10 (a major landmark visible from many of the routes in the experiment) and 15 (the local town) were used infrequently for the spatial tests, but when presented were recognised in a high proportion of cases.

Figures B-3 to B-8 show these results graphically by day and experimental grouping. In these graphs, 0% recognition also records a lack of presentation of that key point.
On day one, key points 1, 10 and 15 were not presented to the control participants and Key points 2, 8, 12 and 13 were not presented to the imagery participants. All other 0% recorded in figure B-2 show a complete lack of recognition of that point, i.e. for the control group: key points 2 and 7 were not recognised at all; for the imagery group all points presented were recognised by some participants.
On day two, key points 10 and 15 were not presented to the control participants or to the imagery participants. All other 0% recorded in figure B-3 show a complete lack of recognition of that point, i.e. for the imagery group: key point 9 was not recognised at all; for the control group all points presented were recognised by some participants.

Figure B-5: Knowledge of key points on day three as a percentage of presentations by experimental group

On day three, key points 10 and 15 were not presented to the control participants or to the imagery participants.
On day four, key points 2, 8, 12 and 13 were not presented to the control participants and key points 1, 10 and 15 were not presented to the imagery participants.
Figure B-7: Knowledge of key points on day five as a percentage of presentations by experimental group

On day five, key points 10 and 15 were not presented to the control participants or to the imagery participants.

Figure B-8: Knowledge of key points on day six as a percentage of presentations by experimental group

On day six, key points 10 and 15 were not presented to the control participants or to the imagery participants.

**Post activity tests using plain panoramic images**

There were 17 panoramic images available for testing. These images had no annotation to aid recognition. Thirteen of these images showed junctions, either t-junctions or crossroads. The number of roads in Table B-5 shows the number of road segments visible in the panoramic image, therefore a crossroads was shown as four road segments, and a straight road as two.

Only three photographs were assessed as showing no significant landmarks. A significant landmark was defined as a particular marker (for example barrier or flagpole), or series of markers which may aid identification of the location.
Table B-5 shows the recognition of the individual photographs as a percentage of the number of times the photograph was presented (i.e., (no times recognised/no times presented) × 100). This percentage includes both those images that could be recognised and a grid reference given, and those that could be recognised only.
<table>
<thead>
<tr>
<th>Photo ID</th>
<th>Junction</th>
<th>No of roads</th>
<th>No of sig landmarks</th>
<th>No of minor landmarks</th>
<th>Significant landmarks</th>
<th>Minor landmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panorama 1</td>
<td>N</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td></td>
<td>Flagpole</td>
</tr>
<tr>
<td>Panorama 2</td>
<td>Y</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>Treeline</td>
<td>Single tree</td>
</tr>
<tr>
<td>Panorama 3</td>
<td>Y</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panorama 4</td>
<td>Y</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>Three barriers on roads</td>
<td>Grooved tank track, many signposts</td>
</tr>
<tr>
<td>Panorama 5</td>
<td>Y</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>Barriers on tank tracks</td>
<td>Many signposts, tank track/road junction</td>
</tr>
<tr>
<td>Panorama 6</td>
<td>Y</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>Barriers on all roads, cattle crush</td>
<td>Signposts, green portaloo</td>
</tr>
<tr>
<td>Panorama 7</td>
<td>Y</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>Large grassy triangle, double road junction</td>
<td>Treeline</td>
</tr>
<tr>
<td>Panorama 8</td>
<td>Y</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>Building, hardstanding</td>
<td>Mast, sea in distance</td>
</tr>
<tr>
<td>Panorama 9</td>
<td>N</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>Hardstanding, bend in road</td>
<td>Treeline</td>
</tr>
<tr>
<td>Panorama 10</td>
<td>Y</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>Double junction, building</td>
<td>Barriers</td>
</tr>
<tr>
<td>Panorama 11</td>
<td>N</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>Treeline</td>
<td></td>
</tr>
<tr>
<td>Panorama 12</td>
<td>Y</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>Culvert</td>
<td>Brown Hill in distance</td>
</tr>
<tr>
<td>Panorama 13</td>
<td>Y</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td></td>
<td>Signpost</td>
</tr>
<tr>
<td>Panorama 14</td>
<td>Y</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>Very wide lead to junction</td>
<td>Junction in distance</td>
</tr>
<tr>
<td>Panorama 15</td>
<td>Y</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>Grassy triangle &amp; brick wall</td>
<td>No entry sign</td>
</tr>
<tr>
<td>Panorama 16</td>
<td>N</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>Bend in road</td>
<td>Trees on hill</td>
</tr>
<tr>
<td>Panorama 17</td>
<td>Y</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>Red barrier, flagpole/sign, grassy track</td>
<td>Plastic covering on barbed wire</td>
</tr>
<tr>
<td>-------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---------------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>Panorama 18</td>
<td>Y</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>Wired enclosure, cattle grid</td>
<td></td>
</tr>
</tbody>
</table>

**Table B-6: Recognition of individual test photos as a percentage of presentations**

<table>
<thead>
<tr>
<th>Test photo ID</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Imag</td>
<td>Contl</td>
<td>Imag</td>
<td>Contl</td>
<td>Imag</td>
</tr>
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<td>Panorama 1</td>
<td>20%</td>
<td></td>
<td>0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panorama 2</td>
<td></td>
<td></td>
<td>50%</td>
<td>50%</td>
<td>100%</td>
</tr>
<tr>
<td>Panorama 3</td>
<td>40%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panorama 4</td>
<td>75%</td>
<td>33%</td>
<td>20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panorama 5</td>
<td>43%</td>
<td>40%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panorama 6</td>
<td>25%</td>
<td>100%</td>
<td>75%</td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>Panorama 7</td>
<td></td>
<td></td>
<td>80%</td>
<td>80%</td>
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</tr>
<tr>
<td>Panorama 8</td>
<td></td>
<td></td>
<td>0%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Panorama 9</td>
<td>25%</td>
<td>33%</td>
<td>50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panorama 10</td>
<td>0%</td>
<td>75%</td>
<td>75%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Panorama 11</td>
<td></td>
<td></td>
<td>0%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Panorama 12</td>
<td></td>
<td></td>
<td>0%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Panorama 13</td>
<td></td>
<td></td>
<td>0%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Panorama 14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panorama 15</td>
<td>75%</td>
<td></td>
<td>0%</td>
<td>0%</td>
<td>40%</td>
</tr>
<tr>
<td>Panorama 16</td>
<td>0%</td>
<td></td>
<td>50%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Panorama 17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panorama 18</td>
<td></td>
<td></td>
<td>20%</td>
<td>20%</td>
<td></td>
</tr>
</tbody>
</table>

It would appear from Table B-6 that Panoramas 1, 8, 11, 12 and 13 are not easily recognised by the participants with 20% recognition or less. Panoramas 1
and 11 show no junctions, but the remainder of these five show junctions and landmarks assessed by the trials personnel as significant.

Panoramas 2, 6, 7 and 10 would appear to be easily recognised by the participants. All of these show junctions and at least one significant landmark.

From Table B-6, of the total of 50 image test conditions, 37 were recognised on less than 75% of the test occasions.
ANNEX C

URBAN EXPERIMENT:

SUPPLEMENTARY DATA
Table C-1: Recognition of key points by experimental condition and test sequence

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Test location</th>
<th>1st test</th>
<th>2nd test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test sequence</td>
<td>First</td>
<td>Second</td>
</tr>
<tr>
<td>Control</td>
<td>Key Point Code</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Control</td>
<td></td>
<td>1</td>
<td>66.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>33.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>100.0</td>
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<tr>
<td></td>
<td></td>
<td>5</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>66.7</td>
</tr>
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<td></td>
<td>7</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
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<tr>
<td></td>
<td></td>
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<td>12</td>
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<tr>
<td>Control + Imagery</td>
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<td>1</td>
<td>66.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>75.0</td>
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<tr>
<td></td>
<td></td>
<td>4</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td></td>
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<td>100.0</td>
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<td></td>
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<tr>
<td>Control -Imagery+</td>
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<td></td>
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</tr>
<tr>
<td></td>
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<tr>
<td>Imagery -Control</td>
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<td>2</td>
<td>66.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
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<td>5</td>
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<td>6</td>
<td>50.0</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>100.0</td>
</tr>
</tbody>
</table>

188
<table>
<thead>
<tr>
<th></th>
<th>10</th>
<th>100.0</th>
<th>100.0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
ANNEX D

COMPONENTS EXPERIMENT:

SUPPLEMENTARY DATA
The following sections highlight the significant findings for each panorama in the test set.

**Panorama One**

A significant effect of condition was found only for the number of contours \((F=4.637, (1,83), P<0.05)\). The prominent group found significantly more contours than the "specific" group, although neither group identified many such features; figure D-1 shows this result graphically.

![Figure D-1: The mean number of contour features identified in panorama one by experimental condition](image)

The group who were asked to identify prominent landmarks within the image identified significantly more contours than those asked to identify specific markers within the panorama.

A significant effect of military specialisation was found for a number of parameters for panorama one, which are summarised in table D-1.
The geographic specialists identified significantly a greater total number of components, lone trees or treelines, road features and fences/walls than the other units. The engineers identified significantly greater number of gates/barriers than the remaining originating units. The specialist unit identified a significantly greater number of ditches and culverts than the remaining units.

A significant effect of role was identified for a number of parameters for panorama one, these are summarised in table D-2.

### Table D-1: The effect of specialisation on the various parameters for panorama one

<table>
<thead>
<tr>
<th>Parameter</th>
<th>F Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of components</td>
<td>$F=12.423, (1, 80)$., $P&lt;0.01$</td>
</tr>
<tr>
<td>Number of lone trees/treeline</td>
<td>$F=2.734, (1, 80)$., $P&lt;0.05$</td>
</tr>
<tr>
<td>Number of gates/barriers</td>
<td>$F=6.191 (1, 80)$., $P&lt;0.01$</td>
</tr>
<tr>
<td>Number of road features</td>
<td>$F=6.235, (1, 80)$., $P&lt;0.01$</td>
</tr>
<tr>
<td>Number of fences/walls</td>
<td>$F=7.842, (1, 80)$., $P&lt;0.01$</td>
</tr>
<tr>
<td>Number of ditches/culverts</td>
<td>$F=12.809, (1, 80)$., $P&lt;0.01$</td>
</tr>
</tbody>
</table>

### Table D-2: The effect of role on the various parameters for panorama one

<table>
<thead>
<tr>
<th>Parameter</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of components</td>
<td>$F=2.455 (1, 79)$. $P&lt;0.05$</td>
</tr>
<tr>
<td>Number of gates/barriers</td>
<td>$F=2.440 (1, 79)$. $P&lt;0.05$</td>
</tr>
<tr>
<td>Number of fences/walls</td>
<td>$F=5.817 (1, 79)$. $P&lt;0.05$</td>
</tr>
<tr>
<td>Number of ditches/culverts</td>
<td>$F=10.731 (1, 79)$. $P&lt;0.05$</td>
</tr>
</tbody>
</table>
Figure D-2: The effect of role on the number of components identified in panorama one

The team leader role appears to have identified significantly fewer components than the technical or the senior NCO roles for panorama one. The difference between the team leader and the team member role approaches significance at the 5% level. There is little difference overall between the other roles in the number of components identified.
Figure D-3: The effect of role on the number of gates/barriers identified in panorama one

The number of gates and/or barriers identified by the specialist role is significantly fewer than the team leaders and team members. The difference between the specialist and technical roles approaches significance.
The technical roles identified significantly more fences/walls than the team leader and the team member roles, there are no significant differences identified between the remaining roles.

![Graph showing the effect of role on the number of fences/walls identified.](image)

**Figure D-4**: The effect of role on the number of fences/walls identified in panorama one

The specialist roles identified significantly more ditches and culverts in panorama one than any of the remaining roles.

**Figure D-5**: The effect of role on the number of ditches/culverts identified in panorama one

A significant effect of condition was found for the number of lone trees/treelines identified ($F=5.328$, $(1,83)$, $p<0.05$), and the number of fences/walls ($F=5.397$, $(1,83)$, $p<0.05$). The "specific" group identified more lone trees or treelines and more fences/walls than the "prominent" group.

The effect of military specialisation was examined for the parameters for panorama two, the significant findings are summarised in table 7-8.
Table D-3: The effect of specialisation on the various parameters for panorama two

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$F$ statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of components</td>
<td>$F=9.541$ (1,80). $P&lt;0.01$</td>
</tr>
<tr>
<td>Number of road features</td>
<td>$F=5.461$ (1,80). $P&lt;0.01$</td>
</tr>
<tr>
<td>Number of buildings</td>
<td>$F=13.437$ (1,80). $P&lt;0.01$</td>
</tr>
<tr>
<td>Number of ditches/culverts</td>
<td>$F=2.510$ (1,80). $P&lt;0.05$</td>
</tr>
</tbody>
</table>

The engineers specialising in geographic systems identified a significantly greater number of total components, number of road features and number of buildings than the other units. The only unit to identify any ditches or culverts in panorama two were the engineers.

The effect of role was investigated on the number of parameters for panorama two. Role was found to have a significant effect on the total number of components identified ($F= 3.481$, (1, 79), $P< 0.01$), and the number of buildings identified ($F= 3.166$, (1, 79), $P< 0.05$).
The team leader and senior NCO roles identified significantly fewer components in total than the technical role and the team leader role identified significantly fewer components than the team member role. There were no significant differences between any of the other roles.

Figure D-7: The effect of role on the number of buildings identified in panorama two
The technical role identified significantly more buildings than either the team member or team leader roles. There were no significant differences between any of the other roles.

Panorama three

A significant effect of condition was found for the total number of components identified \( (F=4.125, \, (1,83), \, p<0.05) \); the number of road features \( (F=8.004, \, (1,83), \, p<0.01) \); and the number of contours \( (F=5.767, \, (1,83), \, p<0.05) \). The “specific” group identified more components and road features but fewer contours than the “prominent” group.

The effect of specialisation was examined for the parameters for panorama three, the significant findings are summarised in table D-4.

Table D-4: The effect of specialisation on the various parameters for panorama three

<table>
<thead>
<tr>
<th>Parameter</th>
<th>( F ) statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of components</td>
<td>( F=5.585 , (1,80), , P&lt;0.01 )</td>
</tr>
<tr>
<td>Number of road markings</td>
<td>( F=3.727 , (1,80), , P&lt;0.01 )</td>
</tr>
<tr>
<td>Number of road features</td>
<td>( F=3.900 , (1,80), , P&lt;0.01 )</td>
</tr>
<tr>
<td>Number of buildings</td>
<td>( F=7.567 , (1,80), , P&lt;0.01 )</td>
</tr>
<tr>
<td>Number of signs</td>
<td>( F=2.588 , (1,80), , P&lt;0.05 )</td>
</tr>
</tbody>
</table>

The engineers specialising in geographic systems identified a significantly greater number of components, road markings, road features and buildings than the remaining units. The only unit to identify any signs in this panorama were the specialists.

The effect of role was investigated on the number of parameters for panorama three. Role was found to have a significant effect on the number of signs identified \( (F=2.937, \, (1,79), \, P<0.05) \).
This effect of role was significant, since only the specialist role identified any signs in this panorama.

Panorama four

No significant effects of condition were found for panorama four.

The effect of military specialisation was examined for the parameters for panorama four, the significant findings are summarised in table D-5.

Table D-5: The effect of specialisation on the various parameters for panorama four

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$F$ statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of components</td>
<td>$F=8.258 \ (1,80)$. P&lt;0.01</td>
</tr>
<tr>
<td>Number of road features</td>
<td>$F=3.175 \ (1,80)$. P&lt;0.05</td>
</tr>
<tr>
<td>Number of fences/walls</td>
<td>$F=5.414 \ (1,80)$. P&lt;0.01</td>
</tr>
<tr>
<td>Number of particular points</td>
<td>$F=3.059 \ (1,80)$. P&lt;0.05</td>
</tr>
</tbody>
</table>

The engineers specialising in geographic systems identified a significantly greater number of components, and fences/walls than the remaining units. The
specialist unit identified a significantly greater number of road features. The only unit to identify any particular points were those categorised as other.

The effect of role was investigated on the number of parameters for panorama four. Role was found to have a significant effect on the total number of components identified ($F= 2.397, (1, 79), P< 0.05$) and the number of contours identified ($F= 2.381, (1, 79), P< 0.05$).

![Graph showing the effect of role on the total number of components identified in panorama four](image)

**Figure D-9: The effect of role on the total number of components identified in panorama four**

The team leader role identified significantly fewer components in total than either the technical or team member roles. There were no significant difference between the other roles.
Figure D-10: The effect of role on the number of contours identified in panorama four

The specialist and officer roles identified significant more contours than the senior NCO, the technical and team leader roles. There were no other significant differences between the roles.

Panorama five

No significant effects of condition were found for panorama five.

The effect of military specialisation was examined for the parameters for panorama five, the significant findings are summarised in table D-6.
Table D-6: The effect of specialisation on the various parameters for panorama five

<table>
<thead>
<tr>
<th>Parameter</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of components</td>
<td>F=4.608 (1, 80), P&lt;0.01</td>
</tr>
<tr>
<td>Number of gates/barriers</td>
<td>F=6.039 (1, 80), P&lt;0.01</td>
</tr>
<tr>
<td>Number of road features</td>
<td>F=4.432 (1, 80), P&lt;0.01</td>
</tr>
<tr>
<td>Number of signs</td>
<td>F=2.588 (1, 80), P&lt;0.05</td>
</tr>
<tr>
<td>Number of ditches/culverts</td>
<td>F=6.039 (1, 80), P&lt;0.01</td>
</tr>
</tbody>
</table>

The engineers specialising in geographic systems identified a significantly greater number of components, road features and fences/walls than the remaining units. The specialist unit identified a significantly greater number of gates and barriers and were the only unit to identify any signs or ditches and culverts in this panorama.

The effect of role was investigated on the number of parameters for panorama five. Role was found to have a significant effect on the number of gates and/or barriers identified (F= 7.342, (1, 79), P< 0.01); the number of road markings identified (F= 2.344, (1, 79), P< 0.05); the number of signs identified (F= 2.937, (1, 79), P< 0.05), and the number of ditches and culverts identified (F= 7.342, (1, 79), P< 0.01).

The only role to identify any gates and barriers, signs or ditches and culverts was the specialists. Only the technical and specialist roles identified any road markings from panorama five.

**Panorama six**

A significant effect of condition was found for the number of particular points identified on panorama six (F=5.283, (1, 83), p<0.05); the "specific" group identified more points than the "prominent" group.
The effect of specialisation was examined for the parameters for panorama six, the significant findings are summarised in table D-7.

*Table D-7: The effect of specialisation on the various parameters for panorama six*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of components</td>
<td>$F=6.466\ (1,79), \ P&lt;0.01$</td>
</tr>
<tr>
<td>Number of contours</td>
<td>$F=4.260\ (1,79), \ P&lt;0.01$</td>
</tr>
<tr>
<td>Number of ditches/culverts</td>
<td>$F=4.467\ (1,79), \ P&lt;0.01$</td>
</tr>
<tr>
<td>Number of particular points</td>
<td>$F=10.731\ (1,79), \ P&lt;0.05$</td>
</tr>
</tbody>
</table>

The engineers specialising in geographic systems identified a significantly greater number of components and contours than the remaining units. The engineers identified a significantly greater number of ditches and culverts and the other unit identified a significantly greater number of particular points.

The effect of role was investigated on the number of parameters for panorama six. Role was found to have a significant effect on the number of ditches and culverts identified ($F= 4.261,\ (1,\ 79),\ P< 0.01$).

Only the team member role identified any ditches and culverts in panorama six.

Panorama seven

No significant effects of condition or specialisation were identified for panorama seven.

The effect of role was examined for the parameters for panorama seven, the significant findings are summarised in table D-8.
Table D-8: The effect of role on the various parameters for panorama one

<table>
<thead>
<tr>
<th>Parameter</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of components</td>
<td>$F=6.423 (1,80)$. P&lt;0.01</td>
</tr>
<tr>
<td>Number of road features</td>
<td>$F=3.795 (1,80)$. P&lt;0.01</td>
</tr>
</tbody>
</table>

The engineers specialising in geographic systems identified a significantly greater number of components and road features than the remaining units.

**Panorama eight**

A significant effect of condition was found for the number of buildings identified on panorama eight ($F=22.301, (1,83), . P<0.01$); the “prominent” group identified more points than the “Specific” group.

The effect of specialisation was examined for the parameters for panorama eight, the significant findings are summarised in table D-9.

Table D-9: The effect of specialisation on the various parameters for panorama eight

<table>
<thead>
<tr>
<th>Parameter</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of components</td>
<td>$F=6.637 (1,80)$. P&lt;0.01</td>
</tr>
<tr>
<td>Number of road features</td>
<td>$F=6.707 (1,80)$. P&lt;0.01</td>
</tr>
<tr>
<td>Number of particular points</td>
<td>$F=2.588 (1,80)$. P&lt;0.05</td>
</tr>
</tbody>
</table>

The engineers specialising in geographic systems identified a significantly greater number of components and road features than the remaining units. Only participants from the specialist unit identified particular points on this panorama.

The effect of role was investigated on the number of parameters for panorama five. Role was found to have a significant effect on the number
contours identified ($F = 2.702, (1, 79)$, $P < 0.05$). and the number of particular points identified ($F = 2.937, (1, 79)$, $P < 0.05$).

\[
\begin{array}{cccc}
\text{Specialist} & \text{Officer} & \text{Team Leader} & \text{Team Member} \\
N = 6 & 12 & 5 & 14 & 23 & 25
\end{array}
\]

**Figure D-11: The effect of role on the number of contours identified in panorama eight**

The specialist role identified significantly more contours than either the team leader or team member roles. The Technical role identified significantly more contours than the team leader role.

Only the specialist role identified any particular points in panorama eight.

**Panorama nine**

No significant effect of condition was found for any measures for panorama nine.

The effect of specialisation was examined for the parameters for panorama nine, the significant findings are summarised in table D-10.
Table D-10: The effect of specialisation on the various parameters for panorama nine

<table>
<thead>
<tr>
<th>Parameter</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of components</td>
<td>$F=4.378 (1,80)$. $P&lt;0.01$</td>
</tr>
<tr>
<td>Number of fences/walls</td>
<td>$F=3.351 (1,80)$. $P&lt;0.05$</td>
</tr>
</tbody>
</table>

Participants from the engineers specialising in geographic systems identified significantly more components and more fences and walls than any of the other roles.

The effect of role was investigated on the number of parameters for panorama five. Role was found to have a significant effect on the total number of components identified ($F= 3.189, (1, 79)., P< 0.05$); the number of road features identified ($F= 2.638, (1, 79)., P< 0.05$); and the number of fences/walls identified ($F= 2.657, (1, 79)., P< 0.05$).

Figure D-12: The effect of role on the total number of components identified in panorama nine

The team leader role identified significantly fewer components in total than the specialist, Senior NCO, officer and Technical roles. The difference between
the technical and team member roles approached significance, with the technical role identifying more components.

Figure D-13: The effect of role on the number of road features identified in panorama nine

The team leader role identified significantly fewer road features than either the Senior NCO role or the Technical role. The technical role identified significantly more road features than the team member role, and the difference between the technical role and the specialist role approached significance with the technical role identifying more road features.
The team leader role identified significantly fewer fences and walls than either the Senior NCO or the technical roles.

Panorama ten

A significant effect of condition was found for the number of fences/walls identified on panorama ten ($F=5.202, (1,83), p<0.05$); the "prominent" group identified more points than the "Specific" group.

The effect of specialisation was examined for the parameters for panorama ten, the significant findings are summarised in Table D-11.

**Table D-11: The effect of specialisation on the various parameters for panorama one**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of components</td>
<td>$F=3.484 (1,80), P&lt;0.05$</td>
</tr>
<tr>
<td>Number of buildings</td>
<td>$F=2.588 (1,80), P&lt;0.05$</td>
</tr>
<tr>
<td>Number of fences/walls</td>
<td>$F=4.029 (1,80), P&lt;0.01$</td>
</tr>
</tbody>
</table>
The engineers specialising in geographic systems identified a significantly greater number of components than the remaining units. Only participants from the specialist unit identified any buildings from this panorama and these participants identified significantly more fences and walls than participants from other origins for this panorama.

The effect of role was investigated on the number of parameters for panorama five. Role was found to have a significant effect on the number of building identified ($F = 2.937, (1, 79), P < 0.05$) and the number of fences/walls identified ($F = 4.495, (1, 79), P < 0.01$).

Only the specialist role identified any buildings within panorama ten.

![Graph showing the effect of role on the number of fences/walls identified in panorama ten](image)

**Figure D-15: The effect of role on the number of fences/walls identified in panorama ten**

The team leader role identified significantly fewer fences/walls than the specialist, Senior NCO and technical roles. The difference between the team member role and the team leader role approached significance, with the team members identifying more fences and walls than the team leaders. The Senior NCOs identified significantly more fences and walls than the officers and the team members. The technical roles identified significantly more fences and walls than the officers.
Table D-12: Summary of the component types where significant effects of specialisation were observed

<table>
<thead>
<tr>
<th>Panorama</th>
<th>Geographers</th>
<th>Engineers</th>
<th>Specialists</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Components, Trees, road features, fences/walls</td>
<td>Gates/barriers</td>
<td>Ditches/culverts</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Components, features, buildings</td>
<td>Ditches/culverts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Components, road markings, road features buildings</td>
<td></td>
<td>Signs</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Components, fences/walls</td>
<td>Road features</td>
<td>Particular points</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Components, road features fences/walls</td>
<td>Gates/barriers signs, ditches/culverts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Components, contours</td>
<td>Ditches/culverts</td>
<td>Particular points</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Components, road features</td>
<td></td>
<td>Particular points</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Components, fences/walls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Components</td>
<td></td>
<td>Buildings fences/walls</td>
<td></td>
</tr>
</tbody>
</table>