"Turn right at the King's Head" Drivers' requirements for route guidance information

by

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Abstract

This thesis addresses a fundamental Human Factors question associated with the design of the Human-Machine Interface (HMI) for in-vehicle electronic route guidance systems: what navigation information should such systems provide to drivers? To avoid the development of systems which demand excessive amounts of drivers' attention and processing resources or which are not satisfactory to the intended user population, it is critical that appropriate information is provided when and where needed. However, a review of the relevant literature revealed a paucity of research concerning this issue.

Six empirical studies are described in the thesis, utilising a variety of methodological approaches. Drivers' preferences for different navigation information are explored via interviews, subjective rating scales and a direction giving exercise. Road trials consider the performance-related benefits of particular types of navigation information.

A consistent finding across the studies was the potential shown for the presentation of landmarks (e.g. traffic lights, petrol stations, and churches) by route guidance systems. Drivers preferred navigational directions which included such information, and incorporated a wide range of different landmarks within their own directions. Significantly, when using a simulated route guidance HMI in which a number of landmarks were presented, as opposed to one in which a reliance was placed on distance-to turn information, drivers made relatively few glances towards the in-vehicle landmark display (on average 1.6 versus 5.0 on a 200 metres approach to a turning), and workload was perceived to be comparatively low.

The thesis has made a contribution to understanding what makes a landmark 'good' for navigation. For everyday discrete objects within the driving environment, the following underlying factors were found to be of greatest importance: the ease with which the location of the landmark allows a navigational manoeuvre (e.g. a turning) to be identified; the visibility of the landmark; and the likelihood of the landmark being mistaken for other objects within the environment (uniqueness). The permanence of the landmark is a prerequisite factor.

A synthesis of the thesis results has enabled the development of a simplistic, yet pragmatic model of navigation. This involves the definition of six distinct components of the drivers' navigation task: trip planning, preview, identify, manoeuvre confirmation, route confidence and orientation. A detailed taxonomy of potentially suitable navigation information is also described, comprising of 76 discrete information elements.

Acknowledgements

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Chapter 1: Introduction to the thesis

"It's a damned long, dark, boggy, dirty, dangerous way"
Oliver Goldsmith (1773/1970, p.14)

1.1 Trends in road transport

The motor car is an integral part of modern society. These self-propelled driver-guided vehicles transport millions of people every day for a multitude of different purposes, e.g. as part of work, for visiting friends and family, or for leisure activities. Indeed, the freedom to drive has widened the "personal spheres of influence" of people throughout the industrialised nations (Sanders & McCormick, 1993, p.696).

Yet the very popularity of cars, and vehicles in general, has resulted in three fundamental concerns (Gerhardt, 1993):-

(1) *Congestion* - the number of cars present on our roads has been steadily rising throughout the 20th century. Forecasts suggest that traffic numbers will continue to rise such that in 20 years time UK traffic levels will be between 36% and 57% higher than they are now (DETR web site, June, 1998). The picture is similar throughout the industrialised nations (Gerhardt, 1993), for example, in parts of the US it has been predicted that by the year 2010 vehicles will spend more time stationary than moving (Barrow, 1991).

(2) *Pollution* - as traffic volumes rise, it is inevitable that environmental damage will increase. The proportion of CO_2 emissions within the UK which can be attributed to transport has risen from approximately 12% in 1970 to 26% in 1994, and is forecast to continue to rise (DETR web site, June, 1998). Problems such as noise and air pollution are already affecting the health and well-being of people, particularly within urban areas (Gerhardt, 1993).

(3) *Road safety* - it has been estimated that half a million people are killed, and 15 million people are injured each year in road accidents worldwide (Hutchinson, 1987; Trinca et al., 1988). Analyses of the causes of accidents point towards the driver as the dominant causal factor. Shinar (1978) has

estimated that human behaviour is involved to some extent in 90% of all road accidents.

1.2 A role for technology

Advancements in information technology and telecommunications have been hailed by many as a means of alleviating some of the negative aspects of the motor car (Gerhardt, 1993; Barrow, 1991). Many terms (with their associated acronyms) have been used in the last fifteen years to refer to this collective group of technologies (e.g. Road Transport Informatics (RTI), Intelligent Vehicle Highway Systems (IVHS), and Advanced Transport Telematics (ATT)). Presently, two terms appear to be in vogue: Transport Information and Control Systems (TICS), and Intelligent Transport Systems (ITS). For the purposes of consistency, the label 'ITS' will be used for the remainder of this thesis.

The central ethos of ITS is that it is the application of technological solutions, rather than basic road building, that is the key to meeting many of transportation's needs. As noted by ITS America, "ITS provides the intelligent link between travellers, vehicles, and infrastructure" (ITS America web site, June, 1998). In this respect, in-vehicle information and support systems are an important facet of ITS. According to Galer Flyte (1995, pp.159-160), such systems can be broken down into those which:

a) "directly impinge on the driving task" - e.g. collision avoidance, intelligent cruise control, lane keeping,

b) "provide information relevant to components of the driving environment, the vehicle or the driver" - e.g. traffic and travel information, vision enhancement, route guidance/navigation,

c) "are unrelated to driving" - e.g. telephones, and office based facilities, such as email, fax and web browsing capabilities.

The ITS central to this thesis is the route guidance system. It has been predicted that such systems will be commonplace in vehicles throughout the developed nations in the near future (Zhao, 1997). Their popularity can already be seen in Japan, where it has been estimated that 1.5 million vehicles already have route guidance systems installed. In other parts of the world (including Europe and the US), there are rising numbers of vehicles equipped with such systems (DETR web site, June, 1998).

1.3 The need for efficient route guidance

A wide range of tools and methods currently exist to help drivers to navigate when travelling on unknown journeys, e.g. road signs, maps (both published and hand drawn), pre-written lists of instructions, and the passenger seat navigator. However, many people still do not choose or follow the most efficient route. As an illustration, the UK Department of Environment, Transport and the Regions estimates that "between 5% and 10% of all vehicle mileage is wasted through incorrect routing and ignorance of traffic conditions" (DETR web site, June, 1998). In an empirical study within the US (King, 1986, p.10), it was found that as much as 20% of the miles driven could be considered to be "navigational waste".

In the 1980s, the UK government assessed the scale of the navigating problem in economic terms. Jeffrey (1981) estimated that national resource savings for the UK (in terms of fuel, vehicle running, road maintenance, accidents and vehicle occupant's time) could be as high as £600 million per year if drivers were provided with more efficient routes. By 1984, a study by the Department of Trade and Industry (DTI) put the figure at £860 million and added that a further £860 million per year could potentially be saved with a real-time system that warned drivers of changing road and traffic conditions (Jeffrey, 1986).

Monetary savings are not the only potential benefits to be gained from efficient route guidance. Considerable difficulties arise from the use of traditional navigating strategies, and most drivers have, at some time, felt the frustration and anxiety resulting from a loss of way. In this respect, paper maps are presently an important source of information for drivers. However, it has been noted that drivers' familiarity with, and possible fondness for, paper maps does not necessarily mean that they are the best tool for meeting human way-finding requirements (Petchenik, 1989). Streeter and Vitello (1986) have acknowledged that map reading is a difficult cognitive task which involves learned rules, and have estimated that 64% of the general population (within the US) experience difficulties when reading maps. Phillips and

Noyes (1977) found that it was common for people to spend a minute or more merely finding a name on a city street map.

Reading a map when driving has predictably been found to be even more difficult, and is inevitably associated with high task workload and large percentages of time spent with the eyes off the road (Fairclough & Parkes, 1990; Wierwille, Antin, Dingus & Hulse, 1989). Furthermore, there is evidence that drivers are well aware of the possible consequences of using a map when driving. Antin (1993) cites a survey of mobile telephone users (Smith, 1978) in which 15 activities were rated on their perceived danger - reading a map while driving was considered to be the most dangerous activity.

With such comments and findings, it is not surprising that many drivers use written notes or sketches for journeys to unfamiliar destinations (Parkes & Martell, 1990). However, even notes and sketches are fundamentally flawed, since information can be inaccurate or misread by the driver, and is of little practical use if a navigational mistake is made (Wickens, 1992).

The difficulties that people experience with the tools and methods currently on offer only reinforce the cost-benefit calculations made in the literature, and strengthen the argument for better ways of providing efficient routes for drivers. The large-scale introduction of electronic route guidance systems into the vehicle environment is seen as a means of satisfying this need (Zhao, 1997; Barrow, 1991; OECD, 1988).

1.4 Technologies for route guidance systems

Various terms are used in the literature when referring to electronic systems that can assist drivers in the navigation task, for instance, navigational aids, vehicle navigation systems, route navigation systems, and route guidance systems (PATH web site, June, 1998). Unfortunately, these terms appear to be used interchangeably in the literature, so for the purposes of clarity, this thesis will use the term "route guidance system" throughout, defined by the author as:-

"an in-vehicle electronic device that can aid drivers in choosing and maintaining efficient routes to their destinations"

This definition is flexible, and places an emphasis on the support of the navigation task, rather than control. Therefore, 'route guidance systems' include systems which do not necessarily give a set route, but instead facilitate the driver's navigational decision making by making information available (e.g. displaying a basic map).

A useful means of conceptualising route guidance systems from a technical perspective is presented by Zhao (1997). He outlines seven basic modules or building blocks for route guidance systems (see Figure 1.1 and the text below). The technical complexity of a given system is defined by the number of different modules that are included from Zhao's diagram.

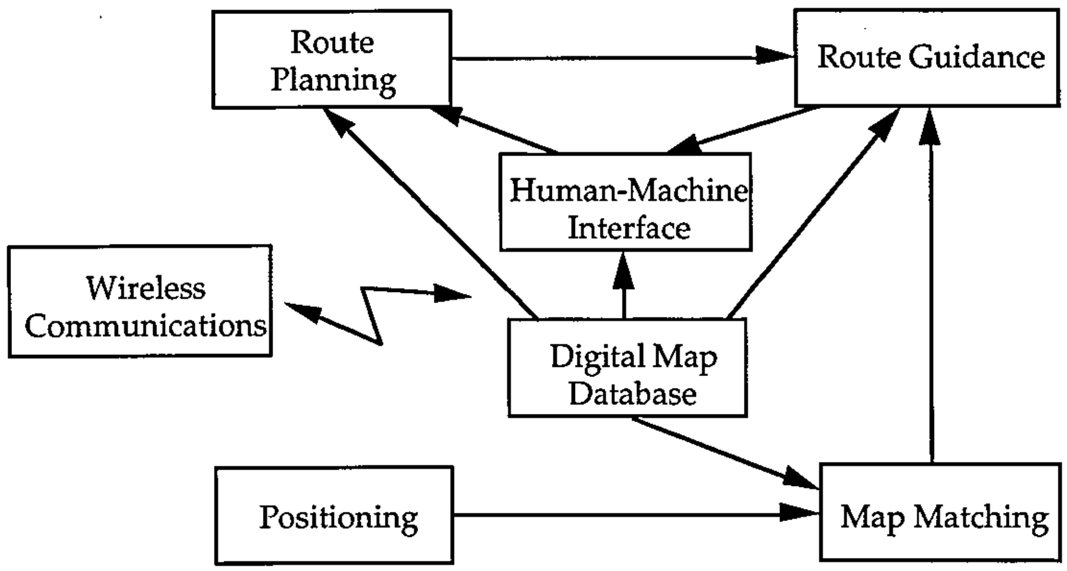

Figure 1.1 - Basic modules (building blocks) for route guidance systems (Zhao, 1997)

A brief description of each of these modules now follows:

Positioning - three technologies may potentially be used to determine the accurate location of the vehicle: stand alone (e.g. dead reckoning using a gyroscope linked to the speedometer); satellite-based radio (e.g. the Global Positioning System (GPS)); or terrestrial radio. As none of these technologies are able individually to provide positioning information to the accuracy often required by a route guidance system, typical systems currently use a combination of methods (usually dead reckoning and GPS).

Map Matching - this method aims to compensate for the accumulative errors associated with dead reckoning, and makes use of the fact that road vehicles are, for the majority of the time, constrained to a finite network of roads. Computer algorithms compare the trajectory of the vehicle against nearby roads/junctions from the map database, and the vehicle's position is reset where appropriate (e.g. when the vehicle appears not to be on a road).

Digital Map Database - this critical information is generally stored digitally on CD-ROM, and incorporates a network of roads/junctions and their attributes, e.g. road labels (street name/number), classes of roads (A, B, Motorway etc.), address ranges, expected driving speeds, direction of traffic flow (one or two way), and any banned turns. In addition, information is increasingly being held regarding landmarks/facilities (usually termed points of interest). The standards committee ISO TC204/WG3 is currently developing a common format for the storage of digital map databases. By encouraging the production of interchangeable digitised maps, this work is likely significantly to enhance the sales of route guidance systems.

Route Planning - this module is concerned with the planning or calculation of routes, either for all vehicles on a particular road network (multi-vehicle planning), or for a single vehicle based on current location and intended destination (single-vehicle planning). In both cases, a variety of algorithms may be utilised based on specific route optimisation criteria, for example, distance, estimated travel time, route complexity, etc.

Route Guidance - this is the process of guiding a driver along a planned route. Two distinct stages exist: manoeuvre generation, in which specific information (e.g. junction type, angles) are extracted from the digitised map based on the recommended route; and route following, in which the timing of any guidance instructions is decided, based on the current distance from manoeuvre, road type, vehicle speed, etc.

Wireless Communications - a number of different technologies (e.g. Radio Data Systems (RDS), short-range beacons, cellular radio) can enable one or two way communications between the vehicle and an external source of relevant information (e.g. a traffic control centre). For the driver, pertinent information might include the traffic conditions along the current route, weather and available parking spaces. By providing such 'quality' information more efficient routes can be planned and followed, ultimately increasing both the benefits and appeal of route guidance systems.

Human-Machine Interface (HMI) - the route guidance HMI provides the means for the driver to interact with the system. Basic technologies associated with the HMI can be classified into those relevant to the *control* of the system, e.g. buttons, keyboards, rotary switches, touch screens, speech recognition; and those concerning the *display* of information, e.g. CRTs, LEDs, LCDs, Head-Up Displays (HUDs), digitised speech, speech synthesis.

1.5 Route guidance HMI styles

Route guidance systems can be classified according to the means by which information is displayed via the HMI. Various attempts have been made to classify HMI styles in the past (e.g. Parkes, Ashby & Fairclough, 1991; OECD, 1988; French, 1986). Unfortunately, such classifications appear dated, given recent trends, and the following is an attempt to remedy this situation. Two fundamental HMI styles are proposed - see Figure 1.2.

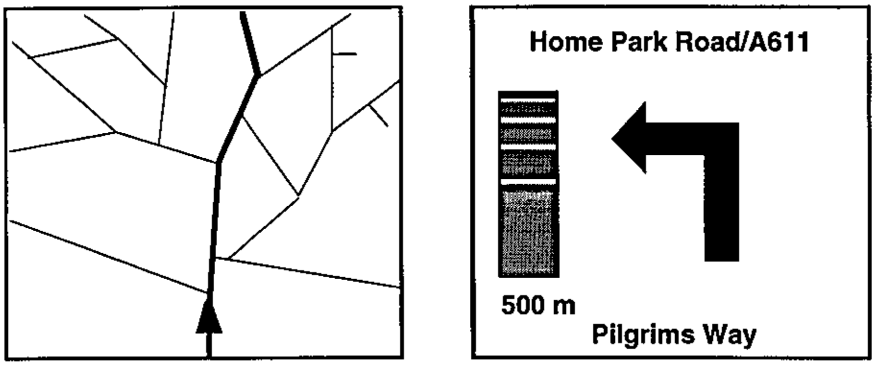

Figure 1.2 - Examples of HMI styles for route guidance systems: Map-based and turn-by-turn-based (basic)

Map-based. - the driver is presented with a scrolling map and the vehicle's current location is indicated by an icon. Early route guidance systems (e.g. the American ETAK™, early versions of Bosch TravelPilot™) did not offer a specific route for the driver to follow, and have been referred to by Parkes et al. (1991) as 'route navigation systems'. More recent map-based systems have shown a highlighted route to facilitate decision making. There are generally two choices for the orientation of map-based displays:

1. Earth fixed/referenced, in which a car symbol moves around a fixed map (usually shown to be North up, although some systems offer the alternative of South-up);

2. Ego-centred, in which the map display rotates around a static car symbol (also known as a moving map display).

Many of the systems that are commercially available within Japan are primarily map-based, and vary according to whether they are earth fixed, ego-centred or both. Some manufacturers, predominately within Japan, are currently offering perspective view map-displays, in which the map is shown from the viewpoint of a low flying aircraft (i.e. in 3D, rather than the more common 2D plan view) - Zhao (1997).

Turn-by-turn based. - The driver is given instructions (using symbols and often voice messages) relating to the location and direction of each manoeuvre. A system's processor can choose how much information is extracted from the digitised map, how this is allocated between the modalities and how the information is then represented (within voice messages and/or visually on screen). There are two approaches to presenting visual information from a digitised map, and these affect the way in which information is represented:-

1. Basic approach, in which the systems' processor 'pulls up' one of a limited library of potential symbols for use with a junction. The route guidance systems' processor will choose which of the symbols is more appropriate based on relevant data associated with the junction (e.g. priorities, angles, junction type). This describes the approach of most route guidance systems (e.g. the aftermarket Motorola Arrow™, Bosch Berlin™ and Navmate™ systems). Systems will vary in how many symbols they store in their database and the rules used for relating attributes of the digitised map to the generic symbol.

2. Junction-specific approach, in which a portion of the digitised map is blown up and then an arrow and other information, e.g. a landmark or banned turns, is overlaid on top of the drawing. This describes the approach of the aftermarket Philips CARiN™ and Alpine systems, in which an accurate representation of the layout of the road is provided.

As a final point, it is worth noting that systems vary in whether they present only turn-by-turn guidance or a map, or both. Furthermore, a differentiation can be made between systems which only permit the use of a map view when the vehicle is stationary (for the purposes of trip planning), and those in which the map representation may be accessed whilst driving.

1.6 Human factors concerns

A risk with the introduction of these systems is that the opportunities offered by the technology are placed above the needs, abilities and limitations of the driver. Concerns have been expressed that drivers may be overloaded by the additional information, and will be distracted from safely controlling the vehicle. For instance, Barrow (1991, p.1248) states that "probably the most time demanding piece of electronic equipment which could be installed in a car is a monitor", whereas Dewar (1988) has expressed concern that the introduction of 'hi-tech' information displays and the availability of large amounts of information (some of it of little value in the driving task) will constitute a safety hazard.

Breaking these statements down, one can see that there are two driver-centred concepts which are critical to the safety-related implications of this technology (Michon, 1993):-

Attention - The use of a route guidance system whilst driving a vehicle is essentially a timesharing activity. Drivers must share their attention between those tasks necessary for the safe control of the vehicle (e.g. lane keeping, spotting potential hazards, etc.), and those related to navigation (e.g. extracting information from display, searching for landmarks, road signs etc.). In this respect, the problems are similar to those posed by other secondary driving tasks, e.g. reading the speedometer, changing cassettes, using a mobile phone, etc. Lack of attention and distraction have been shown to be major contributory factors in many road accidents (Treat, 1980). Therefore, any system which has the potential to add to this problem must be carefully designed.

Mental workload - The uptake of information from a route guidance system places certain demands on a driver's processing resources. Characteristics of the displayed information may lead to situations of 'mental overload'

(Fastenmeier, Haller & Lerner, 1994), for example, when excessive amounts of information are presented, too little information is given, or information is presented in an ambiguous fashion. As pointed out by Alm (1993, p.150), "overload may have an effect upon drivers' abilities to detect important changes in the traffic environment quickly, and to make important decisions during driving".

There are also issues concerning the *acceptability* of such technology (Barrow, 1991). Route guidance systems are unlikely to achieve their market potential if the user population is not satisfied with the products on offer. An important consideration is the confidence that a system bestows on its user, for instance, through providing assurance that the driver is on the correct route.

1.7 Scope and aims of the thesis

Finding one's way or navigating whilst simultaneously driving a vehicle is an everyday, yet complex, task. It has been studied from a number of different perspectives and, as a consequence, it crosses a number of broad academic disciplines. The research presented in this thesis is principally concerned with a human factors or ergonomics viewpoint, and addresses issues associated with the design of the Human-Machine Interface (HMI) for route guidance systems.

An initial review of the relevant literature conducted at the outset of the PhD revealed a paucity of research concerning drivers' requirements for route guidance information. There is a vast amount of different information that could potentially be presented to drivers to support them in the navigation task. Examples of information of relevance include those which are present within the road and surrounding environment, such as landmarks (e.g. in the UK, the popular Public House called "The King's Head"), and those which refer to the environment (e.g. direction of next turning, distance to destination). In order to avoid the development of route guidance systems which demand excessive amounts of drivers' attention and processing resources or are not satisfactory to the intended user population, it is critical that appropriate information is provided when and where needed.

Consequently, the fundamental objective of the thesis is to establish what navigation information should be provided by route guidance systems to support drivers in the navigation task. In specific terms, the following research questions are addressed:

- What are the difficulties that drivers currently experience when using various strategies and types of navigation information?
- What kinds of navigation information do drivers prefer, and why do they prefer certain types of information over others?
- What information do drivers include within their own navigational directions when observing a route as compared to using a set of maps?
- What is the range of information of potential use in supporting the driver's navigation task?
- What are the relative benefits, with respect to driving and navigating performance, of presenting landmarks as opposed to distances within a route guidance HMI?
- Which landmarks could potentially be used by a route guidance system within the UK?
- What are the salient characteristics of landmarks that are of importance when choosing landmarks for use within a route guidance system?
- How can the navigation task be adequately described in order to enable the specification of drivers' information requirements?

1.8 Structure of the thesis

The thesis describes six empirical studies and two literature reviews, each of which address particular issues relevant to the content of information for route guidance system HMIs. An overview chapter then synthesises the various results and knowledge, thereby enabling the fundamental aim of the thesis to be accomplished.

Figure 1.3 is an attempt to show, in general terms, the main thread of the thesis, that is, the human factors issues which have been under investigation, and how the studies and literature reviews fit in relation to one another. The columns refer to the three basic elements of research: existing knowledge; the pertinent issues; and the actual research conducted. For this thesis, as is the case with many research programmes, there is a progression from the investigation of general issues through to more specific concerns.

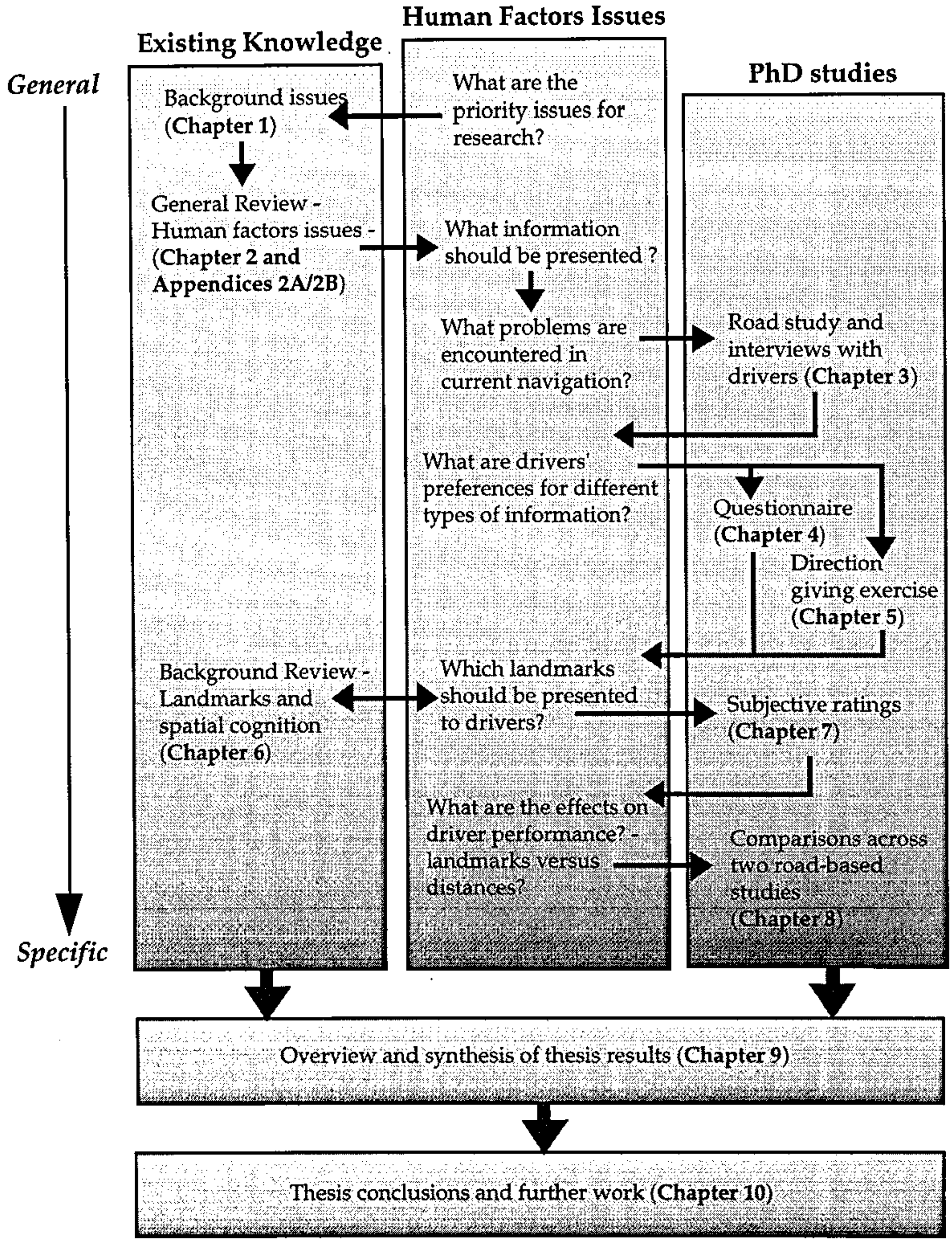

Figure 1.3 - Structure of the thesis

1.9 Chapter-by-chapter summary

The first step of this research was a general review of the 'state-of the art' in human factors knowledge for route guidance systems (Chapter 2). It was clear from this review that a large number of wide ranging issues exist which have been tackled by researchers in this field. The need to identify suitable information types for presentation by a route guidance system was identified as a fundamental issue for which relatively little work had been conducted.

The first empirical work that is reported in this thesis (Chapter 3) aimed to obtain an initial overview of the difficulties that drivers encounter when navigating in an unfamiliar environment. 19 subjects drove alone to two destinations within an urban area, using the navigational method of their choice, and immediately on their return were interviewed regarding their experiences. A number of different problems were reported, broadly concerning the quality of information within the environment, and that within paper maps.

The results of this study also helped to focus the approach taken in a questionnaire survey (Chapter 4), in which 200 experienced drivers were asked a number of questions concerning their preferences for different navigation information. Responses were found to vary as a function of the environment - for instance, formalised information within road signs (e.g. place names, road numbers and junction numbers) were considered most suitable when travelling on dual carriageways and motorways, whereas in slower urban driving, drivers perceived a much greater need for informal, context-based information, such as landmarks, road layout and street names. The study also investigated reasons for stated preference, and some early indications were given as to the factors which dictate good and bad information for navigation purposes.

In Chapter 5, a simulated 'real-world' view of a route (video) was used to establish the information types of perceived use for navigation purposes. In a direction giving exercise, 30 subjects were asked to note down the information they felt they would need to drive the route successfully using either the video, or as a comparative condition, a map with a highlighted route. It was clear from the results of this study that drivers perceived a need for navigation information specific to their particular navigational situation, that is, context-dependent information. This was most evident with respect to the use of landmarks, since subjects expressed a strong need for a wide range of different landmarks (29 distinct types). The data generated in this study also enabled the development of a detailed categorisation scheme for describing information elements of use in the driver's navigation task.

The review in Chapter 2 ascertained that there have been relatively few studies investigating which landmarks to present to drivers. In addition, no human factors empirical work has explored the characteristics of landmarks which make them effective for navigation. On the basis of this finding, plus the outputs of Chapters 4 and 5, it was deemed necessary to carry out a specific review of the background literature from the environmental psychology and human geography fields (Chapter 6). The aim of the review was to establish whether any work of relevance to the use of landmarks in route guidance systems had been carried out within these domains. This revealed knowledge that was consistent with findings within the human factors literature, but little of direct relevance to the specific question - what makes a landmark 'good' for navigation purposes?

In response to earlier work reported in the thesis, Chapter 7 aimed primarily to produce a list of landmarks that could potentially be used by a route guidance system within the UK. The study also aimed to identify the salient characteristics or attributes of landmarks that will be of importance when choosing landmarks for use within a route guidance system. In a computer-based rating exercise, 36 subjects assessed a number of landmarks against each of 11 discrete attributes, as well as an overall task scenario. It was found that traffic lights, pelican crossings, bridges and petrol stations were given the highest ratings. A speculatory factor and regression analysis was used to identify the redundancy in the different attributes of landmarks, and to establish their relative importance.

Chapter 8 aimed to gain some performance-related data regarding the merits of a route guidance HMI in which an emphasis was placed on a wide range of landmarks versus an HMI in which distance-to-turn information was stressed. Comparisons were made across two road-based studies with respect to three dependent variables: navigational errors, visual demand, and perceived workload. The landmark-emphasised HMI performed significantly better in relation to the distance-to-turn HMI. For example, less than a third as many glances were made on the final approach to manoeuvres for the landmark system. Workload was also perceived to be significantly lower. However, a similar number of navigational errors arose for both systems.

Chapter 9 discusses the combined results of the various studies and literature reviews and in doing so forms the basis of a 'first stage' design tool for defining the content of information that should be present within a route guidance system HMI. In the first instance, knowledge gained within this PhD and that present in the literature provides a simple breakdown of the key stages in the navigation task. Modifications are then made to the categorisation scheme proposed in Chapter 5, to provide a list or 'pool' of information that could potentially be presented by a route guidance system. These two outputs enable an assessment to be made as to the suitability of different information elements for helping drivers to find their way. The role of 'context' in the choice of suitable navigation information is discussed.

The conclusions of the thesis are summarised in Chapter 10. This includes a statement of the overall and most important contributions of the thesis to research knowledge and specific future work items. Looking ahead, this chapter also discusses the probable future HMI issues for route guidance systems, based on a consideration of technological developments.

1.10 Background information

The author is employed by Loughborough University working specifically for the HUSAT (Human Sciences and Advanced Technology) Research Institute. Therefore, the thesis has been carried out part-time over a period of approximately five years. During this time, the author has worked on a number of collaborative research projects addressing human factors issues for Intelligent Transport Systems, particularly route guidance systems. Thus, the research reported in this thesis has originated from four primary sources, in which he has had differing levels of responsibilities:

- Personal part-time work - Chapters 1, 2, 5, 6, 9 and 10. Research (experimental studies, literature reviews and overview discussions) undertaken solely by the author for the purposes of the PhD thesis.

- Specific research studies undertaken on behalf of a major car company - Chapters 3 and 4. In both of these, the author planned and carried out all of the data collection. Furthermore, to suit the aims of the thesis, additional components (e.g. driver interviews, extra questions) were added by him to the original work.

- EC funded DRIVE II programme: 'HARDIE' project - Chapter 7. It was primarily the author's responsibility to accomplish this study, however, two of his colleagues at HUSAT were involved in the setting up and execution of this experiment. It is estimated that the author carried out approximately 70% of the planning for this experiment, 50% of the running of subjects and 50% of the original data analysis. More detailed analyses have been carried out by the author since the initial report was written, and the chapter has been written wholly by him for the purposes of the PhD thesis.

- Supervised student projects at Loughborough University (1 MSc Information Technology and 1 BSc Ergonomics) - Chapter 8. The author was heavily involved in the day-to-day supervision of these projects, and for the purposes of this thesis he has re-analysed parts of the original data in order to enable some comparisons to be made across the studies*. The chapter has been wholly written by him.

In addition to the above main sources of data, extensive knowledge of route guidance systems and their varying HMIs has been attained via work conducted by the author within the European-wide, DTI funded PROMETHEUS programme: 'CED9' project, and in various consultancy projects for car companies and route guidance system suppliers.

The design-oriented nature of this thesis reflects the content of the collaborative research projects in which the author has been involved. These projects were steered by both researchers and industry, and thus there has been a general requirement to produce human factors guidelines/ recommendations that can be used by designers of route guidance systems. As a result, the thesis benefits from the fact that the knowledge gained can be readily applied and is particularly relevant to the needs of industry.

* For one of the studies, a complete re-analysis of the glance data was necessary.

As a further point, the need for knowledge relevant to the first generation of route guidance system user has dictated the choice of subjects throughout the thesis. For the most part, the subject samples include a significant proportion of experienced drivers, who make a number of journeys within unfamiliar areas. Such requirements have inevitably led to a bias towards male drivers and a rather homogenous group of people in terms of age (typically in the 40-60 age range). Nevertheless, it has been possible to carry out some individual difference analyses in particular chapters of the thesis.

Chapter 2: Literature review - The human factors issues for route guidance systems

2.1 Introduction

There are numerous human factors issues with regard to route guidance systems, and this chapter provides a critique of the literature most relevant to the current thesis. As a result, the majority of the review concentrates on the literature pertinent to the content of information within the HMI for route guidance systems (section 2.3). Figure 2.1 places this focus in a wider context. The diagram draws loosely on the framework described by Zimmer (1990)* in order to describe three overall research themes for the design of route guidance systems which are consistently referenced within the literature (e.g. Alm, 1990; Pauzié, 1994; Green, 1996). For each, the emphasis within the human factors work has been on variables associated with either the road and its surrounding environment, the route guidance display, or the driver.

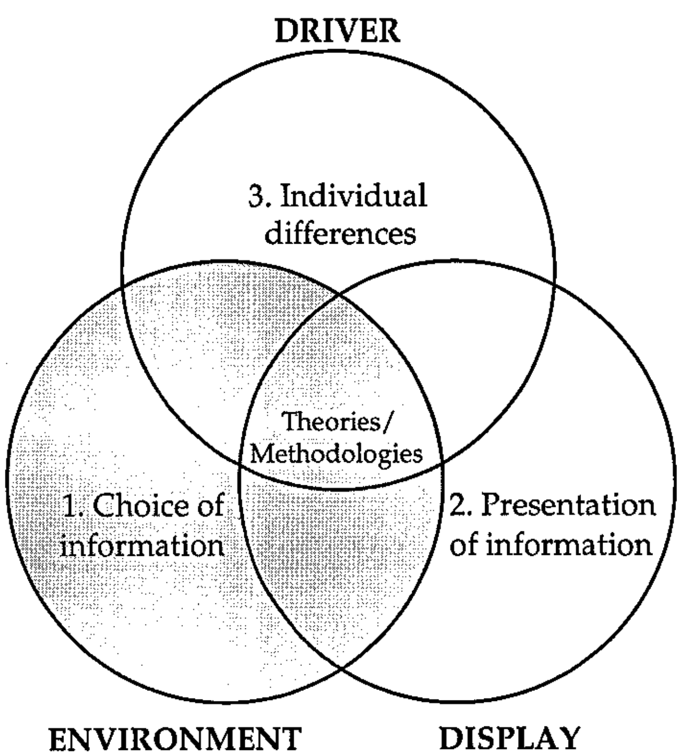

Figure 2.1 - Key human factors research themes for route guidance systems

* Route guidance displays can be considered to be part of Zimmer's Vehicle element.

(1) *The choice of information* - This constitutes the main focus of the thesis, and broadly speaking, can be referred to as the 'what' question. A route guidance system has to decide what information to provide for aiding drivers in finding their way. In this respect, information may consist of actual objects or attributes of the **environment** (e.g. road signs, street names, junction layout or landmarks), or may be used indirectly to refer to or point at aspects of the environment (e.g. direction/distance to turn).

(2) *The presentation of information* - this can be referred to as the 'how' and 'when' questions. Environmental and other information has to be presented to the driver via a route guidance **display*** . This theme covers human factors work which has investigated the design of the information display, for example, which sensory modality to use (visual vs auditory vs combination), the format of information (map-based vs turn-by-turn based), the scheduling of information, use of Head-Up Displays (HUDs), etc.

(3) *Individual differences* - the 'who' question. With regard to this theme, the focus of the research concerns the abilities, habits, preferences, experiences etc. of the **driver**, and the implications these have for the optimal design of route guidance systems.

It was clear from the initial literature review (on all three issues) that researchers have concentrated for the most part on questions pertaining to the second of these research themes. Indeed, there have been a large number of empirical studies addressing information presentation issues, notably the choice of modality and the format of information. As the results of this aspect of the review are not of direct significance to the thesis, they are not included here. However, it is recognised that they may be of general interest to the reader, and so are included as Appendix 2A.

Figure 2.1 demonstrates the overlaps between the themes. Two cross-over issues are of particular relevance to this thesis (namely, the presentation of specific types of information, and any individual differences with respect to the choice of information), and thus reviews on these topics are included in sections 2.4 and 2.5 respectively.

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* In this context, a 'display' may utilise visual and/or auditory modalities.

In addition to the three specific themes described above is a grouping of issues that incorporates all interactions between the environment, route guidance display and driver. Research conducted within this overall theme typically includes theoretical work and methodology-related studies. Section 2.6 describes the models of route guidance system use that are present in the literature. Methodological issues specific to the choice of information for route guidance systems will be discussed in section 2.3.3. General methodology issues (e.g. the selection of research environments, test routes, and experimental measures) were not considered to be pertinent to the current thesis, but of background interest, and so the results of this aspect of the review are included as Appendix 2B.

In the first instance, and prior to the bulk of the review, an overview of the driving and navigating tasks will be given (section 2.2). This will serve to illustrate where navigation lies within the overall driving task, and to place the focus of the work reported in the thesis.

2.2 Overview of the driving/navigating tasks

It is commonly agreed that driving can be conceptualised as consisting of tasks on three hierarchically nested levels, with each level requiring different skills and control from the driver. Although the labels attached to the levels vary in the literature (c.f. Lunefield, 1989 with Michon, 1985), there is a general agreement as to the sub tasks included within each of the levels and the interactions between levels and between levels and the external environment.

For the purposes of providing an overview of the driving task*, the following commonly referenced hierarchical structure will suffice (Michon, 1985) - see Figure 2.2.

In this diagram, the highest, **strategic** level involves the planning of tasks at the most gross task level. This includes making global travel decisions such as the route to be taken and the desired journey time. The **tactical** level entails the planning of concrete manoeuvres throughout the route, and so involves interaction with the immediate environment, including other road

* In an hierarchical view of the driving task, 'navigating' is seen as an integral element.

users. As an example, specific manoeuvres are planned at this level, for example a left or right turn. The **operational** level then involves the highly automated motor execution of the tasks planned at the higher levels, for example, turning the steering wheel, or applying the brake.

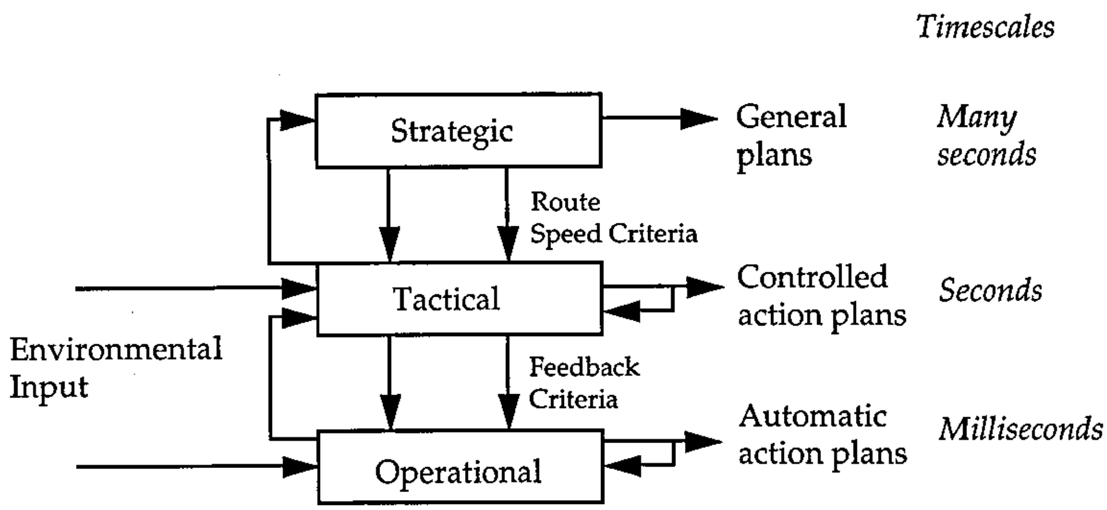

Figure 2.2 - Hierarchical structure of the driving task (Michon, 1985)

An important aspect of this conceptualisation is the variation in temporal demands between the different levels. At the strategic level the time available for processing information is generally long, whereas at the tactical level, decisions have to made in a matter of seconds, dependent on the prevailing situation. Information processing at the operational level is time-critical, such that any delays in the execution of actions will have considerable safety-related implications.

A number of authors have used the well-known work of Rasmussen (1986) to analyse driving-related tasks (Midtland, 1993; Parkes, 1991; Lansdown, 1997). The assumption is that driving consists of sub-tasks that are characterised by three modes of information processing:

(1) *Knowledge-based processing* - occurs in unique, unfamiliar situations for which actions must be planned in relation to goals (i.e. problem solving). An example is planning a novel journey. Activities carried out at this level utilise considerable resources on the part of the driver.

(2) *Rule-based processing* - applies to familiar situations where pre-learnt rules or "know-how" for co-ordinating behaviour can be applied, e.g. overtaking another vehicle. Medium resources are utilised in activities conducted at this level.

(3) *Skill-based processing* - is characterised by highly practised, automatic behaviour controlled by subconscious routines and stored patterns of behaviour, e.g. steering a car. Minimal resources are required for this level of behaviour.

It has been noted that both the hierarchical levels of the driving task (Ward, Fletcher & Hirst, 1994), and the three modes of information processing (Sanders & McCormick, 1993) should be considered as lying on a continuum, rather than existing as discrete levels. Furthermore, any single task, e.g. deciding which way to turn, may involve a mixture of different task and behaviour levels, and, as a consequence, it can be difficult to ascribe drivers' specific information needs to the different levels.

Nevertheless, one can combine the hierarchical view of driving with Rasmussen's modes of information processing to produce a matrix of driving-related tasks (Hale, Stoop & Hommels, 1990). The examples given in Table 2.1 demonstrate how navigation within unfamiliar areas is essentially a strategic/tactical component of the driving task, requiring information processing resources at the knowledge/rule based levels.

		Levels of driving task		
		Strategic	Tactical	Operational
Levels of information processing	Knowledge	Planning unfamiliar trip	Using a paper map en-route	Using vehicle controls for first time
	Rule	Choosing between two familiar routes	Following passenger instructions en-route	Using unfamiliar vehicle controls
	Skill	(Plan) home/ work journey	Negotiating familiar junctions	Turning steering wheel at junction

Table 2.1 - Matrix of driving-related tasks (based on Hale et al., 1990)

2.3 The choice of information

2.3.1 Introduction

Section 2.2 of the thesis introduced the three levels of the driving task: strategic, tactical and operational. In general terms, drivers' navigational informational needs can be assigned to the higher two levels, as follows:

At the *strategic* level, drivers require information such as traffic conditions, estimated journey time, availability of parking places, etc. in order to make overall route decisions. Several authors have addressed the role of these different information types as criteria for route selection (Van Winsum, 1993; Bonsall & Joint, 1992; Wallace & Streff, 1993).

At the *tactical* level, the needs are quite different, and drivers require navigation information such as direction of movement, landmarks, road signs, distance, and road layout to help decide where and when to turn. The relative merits of the different information types at this level of the driving task are critical to the usability (particularly safety-related aspects) of a route guidance system, and constitute the principal concern within this section, and of the thesis as a whole.

Route guidance information content studies can be broken down into those which have aimed to generate suitable information types, and those which have tested particular information types.

2.3.2 Information generation studies

In information generation studies researchers have assessed the content of information extracted by subjects from a particular source. This takes place within the context of a navigation-based task.

Several studies have used drivers' internal models of an area, commonly referred to as cognitive maps, to elicit the information types required for route following. For instance, Obata, Daimon and Kawashima, 1993 (also reported in Daimon, Kawashima & Akamatsu, 1994) conducted a study in which 44, predominately male, students who were familiar with an area were asked to either sketch a map or write verbal directions indicating how to reach the University from their house. The information was categorised using the five elements of a cognitive map proposed by Lynch (1960).

By way of background, Lynch (1960) carried out several influential studies to determine what aspects of a large-scale environment people contain within their cognitive maps, and found that people seem to categorise their environment into five types of element:-

- *Paths* - defined as the channels along which people move, e.g. streets, footpaths, etc.
- *Nodes* - defined as points where several paths meet, e.g. junctions.
- *Landmarks* - defined as external reference points which are easily observable from a distance. Towers, monuments, certain buildings and bridges are examples of landmarks.
- *Districts* - defined as the medium-to-large sections of an environment, which the observer mentally enters "inside of", and are easily recognised as having some common, identifying character, e.g. the city centre, University campus, etc.
- *Edges* - defined as linear elements that serve as boundaries between districts or other areas, for example rivers, walls, fences etc.

In Obata et al's study, the majority of information noted by subjects related to the landmark, node and path categories of Lynch. There was little information noted regarding districts or edges. This result can be explained by the nature of the navigation task, which requires drivers to concentrate on the regions either side of and along the road, and less on the global scene. More information was noted in the map sketches than in the written directions, and the authors believe this result arose because subjects found it easier to explain the routes with a map than with step-by-step directions. Finally, numerous distortions were found in the information provided by subjects. For example, directions and distances were inaccurate, and bends in the road were represented as straight roads. The authors believe this result suggests that a route guidance system need not present accurate 'map-like' knowledge to drivers, and instead may present deformed 'network' knowledge (Freundschuh, 1991).

The same researchers (Obata et al., 1993) also conducted a road-based study in which five male students drove unfamiliar routes using spoken directions provided by the experimenter who knew the area well. The subjects had to request the information they felt they would need to make each decision correctly, and this information was analysed, once again, using Lynch's categories. In common with the paper and pen study, it was found that the results were dominated by path, node and landmark information. Analysis of the drivers' question patterns implied that these information types were predominately used to define and achieve sub-goals, i.e. making the next turn. Furthermore, although the highest percentage of queries made by subjects were of an 'inquisitive' nature (39%), it is interesting to note that 29% of queries were purely for confirmation purposes. A limited breakdown of Lynch's categories was conducted in this road-based study. This analysis revealed that information regarding traffic lights was most commonly referred to (20%), followed by distance to next turn (17%) and information regarding the next node/junction (17%).

Alm (1990) conducted two similar pencil and paper studies which aimed to investigate what aspects or cues from the environment are used by drivers during navigation. In study 1, 19 subjects, split by gender and aged 26 to 55 were asked to provide written directions on how to reach three destinations within the Swedish city of Linköping. In a more extensive second study, 38 subjects, split by gender and aged 20 to 56, were asked to write verbal descriptions and also to sketch maps on how to find three different destinations in the same city. In both studies, subjects lived within or close to the test area and were told that their directions would be used to help someone who did not know the area. All of the destinations were chosen so that the likely routes would include both urban and rural roads. As for Obata et al's work, the classification outlined by Lynch was used to represent the results, and it was found that all subjects predominately used paths, nodes and landmarks to describe the routes. However, Alm's work differs from Obata et al's, in that he broke down the category of landmarks further into several general classes (e.g. buildings, petrol stations, parks) and analysed these data. This breakdown revealed traffic lights to be the most popular landmark, followed by traffic and orientation signs, shops, petrol stations and bridges (together accounting for 82% of all references).

An original and important aspect of Alm's study was that he assessed the reference schemes employed by subjects to indicate a change in direction. He differentiated between global, local and ego-centred schemes using the classification of Gärling and Golledge (1989). The majority of the subjects were found to use egocentric schemes (e.g. turn left) whereas a few used a combination of egocentric and local (e.g. turn left towards the golf course). On the basis of this finding, Alm proposed that a route guidance system should predominately employ an egocentric reference scheme, but may also include a local reference in particular situations (i.e. if a suitable landmark is present) to aid in driver reassurance.

An interesting road-based study was conducted by Schraggen (1990) in which the source of information was not a cognitive map, but traditional paper maps. The principal aim of the study was not specifically to establish the optimum information that could be presented by a route guidance system, but to gain an insight into how drivers navigate under normal conditions and what difficulties they encounter. Twenty-four subjects, split by experience and gender, drove four prescribed routes in the Dutch city of Amersfoort as marked on a map. They were instructed to give verbal protocols explaining what information they were looking for during the journeys. In contrast to the studies described above, Kuiper's theory of spatial knowledge was used to categorise the navigation information verbalised by subjects (Kuipers, 1978). This analysis revealed that most references were made to street names (42% of all utterances), followed by topological information, e.g. road characteristics/types, counting streets, junction angles (25%), landmarks (15%), road signs (14%), and finally metric information e.g. compass directions, distances (4%). These data seem to be consistent with the conclusions of Obata et al. (1993), since Schraggen's drivers also made little use of map-like information (i.e. metric knowledge).

It is interesting that subjects made such extensive use of street names, since a positive relationship was found between reliance on street names for wayfinding and increased navigational errors. Nevertheless, it must be noted that such results are based on the study of traditional navigational strategies, whereby street names may have been used as a primary information source, and not purely for confirmation purposes. Given the fact that street name signs can be poorly visible, inaccurate and misleading, or perhaps not even present (Davis, 1989), it can be expected that increased navigational errors arise from the use of such a strategy.

In a study by Akamatsu, Yoshioka, Imacho, and Kawashima (1994) verbal protocols were again used, in this case to investigate which types of navigation information were being utilised by eight male drivers (age range 25-35, all with at least five years driving experience) finding their way in the city of Tokyo. In this study, types of information are referred to as 'landmarks'. However, a landmark is defined in the text as information used "to identify crossroads and the position of the car" (p.149). As such, the results refer to a variety of different information types (e.g. distance to turn, street names, road signs, buildings).

Subjects used different navigation systems which provided no route guidance, merely a vehicle location symbol on a map display. They were instructed to choose their own route, and to use the system for making navigational decisions en-route. Furthermore, they were asked to verbalise any information they were using during the journey. Half of the drivers were familiar with the area, the other half were not. It is not clear from the paper how those subjects who were familiar with the area were using the navigation system. In addition, the authors do not provide any indication as to the range or extent of information displayed by the systems. The types of information most frequently mentioned by subjects were buildings, street names, the name of an intersection, distances and the name of a place. Together these information types accounted for 73% of all utterances.

2.3.3 Methodology issues - information generation studies

The information generation studies described above can be seen to vary according to the following relevant dimensions: the source of navigation information, the tasks of the information provider and receiver, and the classification scheme used to categorise the information generated. Table 2.2 summarises the different approaches taken by researchers in terms of these dimensions.

	Setting for study	**Information source**	**Task of information provider**	**Task of information receiver**	**Categorisation scheme**
Alm (1990)	Paper & pen	Cognitive map	To write/ sketch directions	To reach destination (imagined)	Lynch (1960)/ Gärling & Golledge (1989)
Obata et al. (1993) - study 1	Paper & pen	Cognitive map	To write/ sketch directions	To reach destination (imagined)	Lynch (1960)
Obata et al. - study 2	Road	Cognitive map	To give verbal information when asked (experimenter)	To ask for information when needed (subject)	Lynch (1960)
Schraggen (1990)	Road	Paper Maps	No information provider	To call out information being used	Kuipers (1978)
Akamatsu et al. (1994)	Road	Map-based Navigation system	No information provider	To call out information being used	Own scheme

Table 2.2 - Review of information generation studies

Information source

A basic requirement for all studies regarding this topic is the availability of a source from which subjects can extract the information types they consider to be appropriate for navigation. Several authors have argued that a route guidance system should present the types of information that are contained within drivers' well-developed internal representations, that is, cognitive maps of the environment. It is claimed that a system that achieved this would present information that matched drivers' expectations, thus allowing easier and faster decision making. As stated by Alm (1990), in this situation the route guidance system and driver will talk the same "language".

However, it is apparent that such a source may not be as ideal as claimed. For instance, the results obtained are wholly dependent on the characteristics of the area in which the study is being carried out (e.g. road and junction types, availability of different landmarks). As a consequence, it can be difficult to be sure of the applicability to other environments of any conclusions reached. Furthermore, there are indications within the background environmental psychology and human geography disciplines that there are inherent biases in our specific knowledge of the environment - this issue will be dealt with in more detail in Chapter 6.

The use of a paper map or a map-based navigation system as a basis for suitable information types can also be criticised. A map is a limited information source, and, as mentioned in Chapter 1 it is well documented that people experience difficulties in extracting relevant information from maps (Streeter & Vitello, 1986).

There are two alternative information sources which do not appear to have been exploited in the literature:-

(i) *Actual observation of route* - it could be argued that the information which a driver actually sees on a journey and identifies as relevant for navigational decision making is the best basis for the content of information for a route guidance system.

(ii) *General knowledge of driver* - driving in an unfamiliar area is a task that most people have carried out on many occasions. As a result, drivers' long-term memories will contain considerable knowledge regarding the merits of different types of information for use in the navigation task.

With respect to (ii), one might expect that surveys of traditional navigational habits and preferences of drivers might reveal some interesting data regarding the use of particular information types for route following. However, examination of the relevant literature (e.g. Streff & Wallace, 1993; Parkes & Martell, 1990, Streeter & Vitello, 1986) shows that such studies have concerned themselves with current sources of information (e.g. maps, notes, passenger), as opposed to specific types. It could be argued that a potential source of valuable knowledge has, therefore, not yet been examined. It is evident that asking drivers which types of information they consider to be of most use for helping them find their way, and perhaps more importantly, asking why they feel this way, could provide a significant insight into the route guidance information content issue.

Tasks of information provider/receiver

Several of the studies described above have relied on people acting as an information provider in the context of giving directions for an imaginary person. The content of these directions are subsequently examined by researchers. Alm (1990) has argued that practical considerations, such as the short time necessary to obtain data and the possibility of using a large number of subjects and situations, render this a good method.

However, there are concerns over the use of this procedure. For instance, people differ considerably in their ability to provide directions (Streeter & Vitello, 1986), and, as a result, such studies require (a) a large number or a specific group of subjects, and (b) the testing of the generated information. Furthermore, it is likely that subjects will be prudent in the detail of their directions (i.e. there will be redundancy), so it is difficult to know which information is considered important. Alm (1990) provides a final point of criticism regarding direction giving studies when he states that, since information is not being generated in the context of the driving task, there is a loss of realism.

As an alternative to direction giving studies, researchers have conducted road-based experiments in which subjects have verbalised either the information they require or the information they are using. As stated by Alm (1990) such studies suffer from the disadvantages that they can be extremely demanding on resources, and require a large number of subjects and different driving conditions to reflect the cognitive models of the general population.

Furthermore, there are concerns related to the suitability of verbal protocols in the driving context. Parkes (1991) believes that the very act of driver introspection can negate the results, since stimuli which have no effect may be reported by subjects, whereas minor or even major influences may be omitted. Alm (1990) points out that the navigation task itself is highly demanding and reduces the possibility for drivers to verbalise their processes.

As a compromise solution, Alm has suggested that both methods should be used when investigating the content of information for route guidance systems.

Categorisation of Information

In order to make meaningful interpretations of the data produced in information generation studies, categorisation must be applied. The majority of the studies described above have utilised the results of work related to cognitive maps and mapping to act as a categorisation scheme (i.e. the work of Lynch (1960), Gärling & Golledge (1989), and Kuipers (1978)). However, it is felt that such schemes are at too gross a level to enable the results of studies to be easily applied by the designers of route guidance systems - it must be noted, though that this has been realised to a certain extent by researchers (Alm, 1990).

There have been some other categorisations of the information content within a route guidance HMI which are of practical value (e.g. Serafin, Williams, Paelke & Green, 1991; Mollenhauer, Hulse, Dingus, Jahns & Carney, 1997). For instance, Serafin et al. (1991) list 28 information elements, broken down into those relating to general (e.g. brightness), orientation (e.g. distance to next cross street), route guidance (e.g. display next instruction(s)) and trip planning (e.g. display destination) "features" of the system. The elements were determined via a review of the functionality of current route guidance systems and expert opinion. Unfortunately, it is evident that such breakdowns are at a relatively high level of generality, and, as a result, it becomes difficult to consider the relative benefits of different information for supporting the navigation task.

In summary, what would seem apparent is the need for a more detailed and comprehensive taxonomy which can be used directly by designers to make choices as to which information should be presented by a route guidance system.

2.3.4 *Information testing studies - landmarks*

Information testing studies generally involve some form of comparison between route guidance systems offering different types of information to the driver. The majority of these studies have contrasted driver behaviour and performance for systems which employ landmarks with systems which do not.

For instance, Alm, Nilsson, Järmark, Savelid and Hennings (1992) conducted a road trial in which 20 drivers used a simulated route guidance system that provided simultaneous visual and aural directions. The design was factorial, such that in the control group 10 drivers (matched by gender only) were presented with only very simple left/right/straight on information, whereas in the experimental group, the remaining subjects received the same information plus information regarding landmarks along the route.

Subjects in the landmark condition felt significantly more confident as to where to turn ($p<0.05$). No further statistical differences were found between the two conditions. However, several non-significant trends were revealed by the data. For instance, subjects presented with landmarks generally felt more satisfied with the content of visual information and rated their mental workload (using the NASA-TLX) to be lower. Furthermore, there were fewer navigational errors made by those who were presented with landmarks.

However, this study was primarily subjective in the measures taken, and, as pointed out by Alm et al., the route was not very complex (15 decision points over a 3.5 mile journey which took on average 7 minutes to drive) and few landmarks were presented to the driver (only traffic lights on six occasions). Consequently, the relative effect of landmark use on the usability of the route guidance system may have been limited.

Green, Hoekstra, Williams, Wen and George (1993a) conducted a study whose principal aim was to examine the feasibility of using a simulator for conducting route guidance evaluations. However, the study also investigated the potential for presenting landmarks to drivers. A sample of 48 subjects, split equally by gender and age, sat in a mock-up of a car and watched a videotape of an unfamiliar 25 minute trip through the state of Michigan, North America. They received route guidance and traffic information during the journey. The design was factorial with four conditions: visual route guidance information only, visual with landmarks, auditory route guidance information only, auditory with landmarks. The landmarks used were traffic lights, stop signs and bridges. Subjects were instructed to press one of three buttons when they could see the junction referred to by the system (left/ right/straight on), and to press the brake pedal if the car in front braked.

Subjective data, as opposed to performance-related variables, revealed the most differences with respect to the effect of landmark presentation. For instance, it was found that drivers strongly preferred HMIs that contained landmarks over those without. In commenting on this study, it must be noted that, in addition to landmarks, a number of other types of information were presented by the simulated route guidance system , including street names (which may be considered as landmarks in their own right), accurate road layout and compass directions. Use of such a wide range of supporting information types may have negated any potential effect that landmarks could have on objective performance.

Of those studies found in the literature, only one empirical study has explicitly revealed performance-related benefits for a route guidance system that utilises landmarks. Bengler, Haller and Zimmer (1994) conducted a simulator-based experiment in which 24 experienced drivers aged 21-49 viewed a series of videotaped routes whilst carrying out a simple tracking task (i.e. using the steering wheel to keep a computer-generated cross in the centre of the road view). A factorial design was employed, such that half of the subjects were provided with visual only route guidance information - a simplified representation of the junction with no other information. The remaining subjects were also provided with landmark information at junctions. It is not apparent from the paper as to the range of landmark types presented, or the complexity of the routes followed. However, the authors do provide traffic lights and stop signs as examples of landmarks in the introductory section. Subjects were instructed to use the route guidance information to make navigational decisions, and to register their judgements by turning the steering wheel and employing the indicators. Three types of indicator/steering error were registered: those in which the driver reacted too early and had to correct his/her action; those in which the driver reacted too late or not at all; and those in which reactions were in the wrong direction. Therefore, these parameters were being used to indicate navigational, rather than driving, performance. Route guidance information that included landmarks was found significantly to reduce the number of incorrect uses of the indicators for all three error types. There was also a trend for reduced steering errors with landmark information (approximately 30% fewer errors), but this difference was not significant.

In addition to the above studies, some researchers have listed generic 'good' landmarks, on the basis of their own overall evaluations of route guidance systems which employ a limited number of landmarks. For instance, Green, Levison, Paelke and Serafin (1995) report on a series of simulator and road-based trials in the American state of Michigan in which different versions of a simulated turn-by-turn route guidance system were evaluated (Green et al., 1993a; Green, Williams, Hoekstra, George & Wen, 1993b; Green, Hoekstra & Williams, 1993c). The system included traffic lights, stop signs and bridges as landmarks. These types of information were rated as being very useful for navigating, and the authors conclude that such generic landmark classes should be the minimum offered by a route guidance system.

Davis and Schmandt (1989) conducted less formal evaluations of a speech-only prototype route guidance system in the American city of Boston. Approximately 40 people drove a vehicle equipped with the system during its developmental phase. Changes were made to the system as a result of drivers making negative comments or wrong turnings, as part of an iterative design process. Favourable remarks were made regarding the use of traffic lights, stop signs, bridges and petrol stations as landmarks - J.R. Davis (personal communication, September, 1996).

2.3.5 Discussion - choice of landmarks

Table 2.3 summarises the nature of the key studies described above and the landmarks reported to be of importance for use by route guidance systems.

Authors	**Nature of study**	**'Good' landmarks**
Alm (1990)	Route descriptions given by locals of Linköping, Sweden.	Traffic lights, traffic and place name signs, shops, petrol stations, bridges
Akamatsu et al. (1994)	Verbal protocols given when using navigation systems in Tokyo, Japan.	Buildings, street name signs, crossroad signs, place name signs, traffic signs
Davis & Schmandt (1989)	Evaluation of speech-only route guidance system in Boston, USA.	Traffic lights, stop signs, bridges, petrol stations
Green et al. (1995)	Evaluations of simulated route guidance system in state of Michigan, USA.	Traffic lights, bridges, stop signs

Table 2.3 - Summary of studies regarding the choice of landmarks for use by route guidance systems

In comparing these studies, it is interesting to note that traffic lights are the most appropriate landmark for use in the European and American studies, but receive no mention in the Asian study by Akamatsu et al. The authors do not disclose whether this result arose because traffic lights are rarely used or available as landmarks in Tokyo or, the more likely option, that the navigation systems used in the experiment did not provide such information.

With respect to the other landmark types, there are similarities in those which are considered to be good choices, but notable differences can also be seen. A salient example is provided by the Akamatsu et al. study, in which signs with the name of a crossroads were used as a landmark, since within the UK there are very few areas where such landmarks are found. Indeed, Akamatsu et al. mention that the types of landmarks they obtained were a function of the environment in which they carried out the trial.

Such contradictory results suggest the need for a method of obtaining potentially useful landmarks which is independent of the environment in which the study is carried out, that is, a method which is applicable to all countries and areas. In addressing this concern, it would be important to establish the specific characteristics or attributes of a landmark which will influence the ease with which it can be processed and remembered. Alm (1990), Akamatsu et al. (1994) and Green et al. (1995) have all commented on this issue.

Alm suggests that people consider some landmarks to be more useful than others for navigation purposes primarily because of their commonality across urban areas. Furthermore, he states that popular landmarks tend to be visible in most conditions, and are easy to differentiate and learn. In agreement to a certain extent, Akamatsu et al. feel that the landmarks commonly referred to by subjects in their study were visible from a distance, unique in appearance, and were close to or part of the road infrastructure. Green et al. have also stressed similar characteristics of 'good' landmarks. They feel the best landmarks are those which can be seen at a great distance (at all times), are close to the road, near intersections, and are relatively permanent.

It is apparent that the 'common sense' observations made by all of these authors are rather casual. No human factors study to date has addressed exactly which characteristics or attributes of an object within the physical environment result in it being used as a landmark for navigational purposes.

As a further point, in comparing the various landmark choice studies, it becomes apparent that authors have differed in how they have defined landmarks. For instance, Alm has not included street name signs as landmarks. Instead, he utilises the categorisation developed by Lynch (1960), and defines such signs as providing information pertaining to paths (the channels along which people move, e.g. streets, footpaths, etc.). In contrast, Akamatsu et al. include street name signs as landmarks.

2.3.6 *Information testing studies - other*

In a study by Schraggen (1991) it was not landmarks under investigation, but the use of existing road signs. He conducted a road-based study testing three simulated navigation systems which presented different types of information. In a repeated measures design, 42 subjects, split by gender, who were unfamiliar with the test area, drove three routes in the Dutch city of Amersfoort. Each route required driving on one of three different road types, either highways (motorways), main roads within the city, or residential roads. Subjects navigated on these routes using either simple left/right arrows displayed on cards (which showed the angle of turns), instructions that utilised road signs (e.g. "follow signs for Utrecht"), or multiple instructions (2/3 instructions at one time which utilised both street names and road sign information). In terms of navigation errors, subjective workload estimates and questionnaire data, subjects performed worse on all measures with the multiple instructions. There were few differences between the simple arrows and the road sign instructions, and the author believes a ceiling effect may have arisen (i.e. the navigation task was too simple), since few navigational errors arose, and subjects generally rated the simulated systems positively.

Preference data revealed some differences, since 48% of the subjects preferred the arrows only, 12% preferred the road signs only, 17% had no preference, and 24% preferred a combination of road signs on highways and arrows on other roads. None of the subjects preferred multiple instructions. On the basis of these results, the author concludes that road signs seem equally effective as compared with simple left/right arrows, but based on the preference data it would seem appropriate to use arrows on city roads and road sign instructions on highways.

Dicks (1994; also Dicks, Burnett & Joyner, 1995) conducted a road-based study which focused on the interaction between modality and complexity of information. 16 subjects took part in the experiment (13 males and 3 females), age range 41-60. Each subject drove two routes in the suburbs of Leicester, UK, one using visual route guidance information alone, and the other using the visual information plus simple auditory instructions (e.g. "take 2nd turning left"). The level of road layout information presented in the visual modality varied, so that half of the subjects were presented with simple visual information (basic directional arrows) and the other half with complex visual information (full plan view representation of junction layout). In addition, all subjects were presented with street names (visually only) randomly throughout the route.

Although few statistically significant differences were found with respect to the simple/complex display factor, it was evident that drivers generally made longer and more frequent glances towards the complex visual display, as compared with the simple display. In contrast, there were trends for subjects to make more navigational errors when using the simple visual information. Further analysis revealed that the majority of these errors occurred when negotiating more complex manoeuvre types (e.g. large multi-exit roundabouts). This situation can be likened with that encountered during the use of simple auditory instructions (Green et al., 1993a; Alm et al., 1992), and reflects the difficulties of adopting a generic approach to symbol design given the inherent variability in the road environment.

Subjects reported that they felt more confident about making a manoeuvre when they were presented with the street names ($p<0.05$), although the presentation of street names led to longer glances towards the visual display. As noted by the authors, this result represents the trade-offs between increased acceptability of a system via the presentation of non-essential confirmatory information, and the inevitable increases in visual demand that will result from more information being present on a display.

Route guidance systems are able to provide information following a manoeuvre intended to warn the driver in advance of the next turning. Information of this type has been labelled pre-information, and a road-based study by Burnett, 1992 (also Burnett & Parkes, 1993) aimed to establish the usefulness of this form of message. 16 subjects (split by gender, predominately in the 20-30 age group) drove two matched routes, one using simple visual route guidance symbols together with a graphical distance to the next turn, and one with the same visual information plus an additional simple voice instruction. In addition, half of the subjects were provided with a pre-information message, warning them of the nature of the oncoming manoeuvre and distance remaining (given after the previous turn).

The pre-information messages were considered by all subjects to be at least 'helpful' in the navigation task, although their presentation inevitably increased the visual demand of the interface. Furthermore, some negative comments were made regarding the temporal aspects of presenting this information. The pre-information symbols were only presented for five seconds following a manoeuvre, and subjects commented that they felt pressured into looking at the display whilst still in the process of accelerating to a 'cruising' speed. Some subjects also confused the pre-information and final approach messages, which, on occasion, led to navigational errors (a result also found in a more recent study by Pauzié and Forzy, 1996). These problems highlight the need to ensure different display modes are suitably differentiated by appearance, colour, location within the display, etc.

2.4 How to present particular information types?

2.4.1 Road layout

By its very nature, a route guidance system will provide some description of the oncoming manoeuvre (referred to here as road layout information). A component of road layout information is the angle of the oncoming manoeuvre. Verwey and Janssen (1988) note that the navigational errors arising in the visual only condition of their road-based study (see Appendix 2A for a detailed description of this study) could be attributed to using right-angled arrows for all turnings. In other words, drivers expected congruence between the visual representation of junction angle and the actual angle. The fact that significantly fewer errors arose in the auditory only condition, even though no junction angle information was provided (e.g. "go left"), can be explained by the theory of stimulus-response compatibility (Verwey, 1989), that is, incongruence is more critical for spatial information, since the response required (making a turn) is spatial.

A further issue regarding the presentation of junction layout information is concerned with the orientation of the visual symbols. James, Ehert and Philips (1995) conducted a short review of orientation issues associated with displays, in which they noted that the time to make a match between two objects that are non-congruent is a linear function of the angle between them

(Shephard & Metzler, 1971). In other words, mental rotation has to occur. A user of a route guidance system will have mentally to rotate the displayed image to match with the outside view - this may be in vertical and/or horizontal planes. Therefore, one would expect improved reaction times for route guidance symbols that accurately reflect the view of the driver.

Green and Williams (1992, see also Appendix 2A) examined such a possibility via a simulator experiment. Three options for the presentation of road layout information were considered: a plan view (requiring 90 degrees rotation); an aerial view (offering a symbolic representation of the image that a low flying aircraft may see of the road ahead); and a perspective view (drivers' view of the road scene). The aerial views led to significantly reduced reaction times in relation to the plan view (1501 vs 1523 ms). Surprisingly, the perspective view performed worst of all with a mean reaction time of 1706 ms. In discussing this result, the authors considered that the plan view had the advantage of representing the internal view of the road network (i.e. an abstract description of nodes and links), whereas the potential advantage of the perspective view (representation of the same view as seen outside the windscreen) was heavily confounded by its 'squashed' look. The aerial view appears to contain more of the advantages of the two, and less of their inherent disadvantages. As the authors admit, such findings would need to be confirmed by real road experiments, if this style of symbol presentation is to be adopted within standards.

2.4.2 Distance to turn

An information element which is present in all current route guidance systems is that which informs the driver as to the distance remaining prior to the next manoeuvre. According to Downs and Stea (1977), there are three different formats of distance representation within drivers' cognitive maps of the environment. These can be interpreted as modes of presenting distance to turn information to drivers. The examples below reflect some display options.

- Absolute (e.g. 300 metres, 1.3 miles)
- Relative (e.g. "half way there", an 'emptying' countdown bar)
- Costs (e.g. time - "soon"; energy - "a long way")

To date, there have been no studies which have empirically addressed the merits of different design options for the presentation of distance to turn information. Some problems with options have been reported within the context of system evaluations or studies investigating other issues. For instance, Srinivasan, Landau, Hein and Jovanis (1994) note on the basis of a simulator study (described in Appendix 2A) that subjects found a countdown bar used as part of a Head-Up Display symbol to be confusing, and, as a result, drove more slowly than subjects using a map-based display. The bar showed relative distance values (i.e. each of four segments represented a quarter of the distance between manoeuvres). Although the authors do not make this point, it is likely that the fundamental inconsistency in this approach (the distance represented by a segment changes for each manoeuvre), made it difficult for drivers to gain an appropriate mental model of the distance 'system'.

In a series of iterative design studies, Green et al. (1995) withdrew a time-based countdown bar from their final recommended interface (the countdown bar consisted of a number of segments each representing 20 second intervals). Subjective feedback was the reason given for this decision, since drivers preferred the absolute distance values (e.g. 0.1 miles) over the time-based information. Unfortunately, the authors provide no reasons as to why this result might have arisen.

Some positive comments have been made with respect to the use of countdown bars. In a recent paper (Winkler & Nowicki, 1997), questionnaires were received from 364 drivers who rented cars with a Bosch route guidance system. With respect to the approach of using countdown bars, it is noted that this "proved to be efficient", although no further information is given. Furthermore, in evaluations of the Travtek system in Orlando, it is noted that the countdown bars "aided drivers in anticipating and executing manoeuvres" (Carpenter et al., 1991), although, again, no specific reasoning is provided.

2.4.3 Landmarks

It will be extremely important for the design of a route guidance system to establish exactly how to present landmark information to the driver. A poor visual and/or aural representation of a landmark is likely to lead to driver confusion and increased workload, which in turn may reduce the overall acceptability of the system and have consequences for overall driving safety. This issue is of particular importance for the development of standard iconic representations of landmarks for use in visual displays.

Recently, a road-based study has been conducted which aimed specifically to establish effective ways of visually presenting landmarks within a route guidance system (Pauzié, Daimon & Bruyas, 1997). Two approaches were examined: a generic presentation (e.g. the same visual icon for all churches); or a specific presentation (e.g. a representation of a given church). In an urban driving environment, 10 subjects negotiated a route using a simulated route guidance system in which turn-by-turn directions (visual only) were provided. No further details are given regarding the nature of the route or the characteristics of the subject population. Generic/specific representations of landmarks were randomly presented throughout the route (i.e. a repeated measures design), in addition to basic junction layouts. Landmarks such as churches, bridges, parks, car parks, railway stations, shops, banks and restaurants were included in the system design.

It was apparent from driver feedback that the familiarity of the landmark representation was the most important factor determining whether drivers considered the specific or generic design to be more useful for navigation. For instance, specific presentations that included a well-known logo or name (e.g. MacDonalds, Natwest) were preferred to their generic equivalent (e.g. a symbolic representation of a burger, coins and notes). In contrast, in situations where the generic design was familiar (e.g. a church icon), the more detailed specific representation was generally rated less favourably. Not surprisingly, in these cases, there was some evidence that longer glances were made towards the visual display that included the more complex landmark design.

Such results appear to be of particular relevance to the choice of landmarks, although this is not mentioned by the authors. Given likely name changes in landmarks such as public houses, restaurants, banks, shops, etc., landmarks that lend themselves to a generic presentation may be preferable for use within a route guidance system.

In addition to this work, there have been several studies which have assessed a particular representation of a landmark as part of an overall route guidance system evaluation. Of these, Green et al. (1995) are the only authors to use the results of their evaluations to make some points regarding efficient means of representing landmarks. In their paper outlining some preliminary guidelines for designers, they state that landmarks should be provided both visually (as graphics, rather than text) and aurally. Furthermore, they specify that traffic light and stop sign graphics should be placed in the centre of the intersection representation. Although such a recommendation would appear to constitute good human factors practice, it should be noted that the evaluations were conducted in the state of Michigan, USA which has a predominantly grid-based road layout. It is possible that this particular guideline would be more difficult to achieve in cities which have more complex junction layouts.

2.5 Individual differences

2.5.1 *Introduction*

This section will provide a summary of driver individual differences in relation to the choice of information for presentation by electronic route guidance systems. Unfortunately, there have been relatively few specific studies addressing individual differences in this field. This is despite the fact that it is well documented that, in the general HCI field, (a) individual difference effects account for considerably more of the variability of performance than do experimental design variables, and (b) a significant part of the variation in user performance can be predicted and comprehended (Egan, 1988). Understanding the effects of individual differences will be an important step towards the goal of designing optimal systems to accommodate different users.

2.5.2 *Ageing effects*

It is frequently stated that the western world population is an ageing one. For example, in the UK in 1993 those over 50 constituted 40% of British adults (+16). Projected growth rates suggest that the proportion of over 50s will grow to approximately 48% of the adult population by 2021 (Coleman, 1993).

It is not surprising then to find that the effect of age on a driver's ability to use a route guidance system has received the greatest attention from human factors researchers. Several age-related factors are discussed in the literature which have implications for the HMI for route guidance systems (Burns, 1997b; Marin-Lamellet, Pauzié & Chanut, 1991; Yanick, 1989):-

- Perceptual changes (e.g. reductions in visual field, static and dynamic acuity, depth perception; increases in glare sensitivity, accommodation time and time required for dark adaptation; poor hearing)
- Cognitive changes (e.g. reduced spatial ability; greater problems in tasks involving dividing attention, attention switching and selective attention)

There appear to be no empirical studies in the literature that have directly addressed the implications of ageing for the content of information for route guidance systems*. However, there are several other results of indirect relevance, for instance, a number of authors have found that older drivers experience greater visual demand with in-vehicle displays than do younger drivers (Graham & Mitchell, 1997; Green et al., 1993a; Noy, 1989; Pauzié & Marin-Lamellet, 1989). Furthermore, Walker, Alicandri, Sedney and Roberts (1991) found in a simulator experiment that older drivers were prone to make more navigational errors as task difficulty and display complexity increased. Such results would suggest that careful consideration should be given to the choice of information for use by this group of drivers, and the distribution of information across the visual/auditory modalities and verbal/spatial formats.

2.5.3 Gender differences

It is certain that there are differences between males and females in current navigational behaviour. As an illustration, a survey conducted by Streff and Wallace (1993) in the US found that paper maps were used more and preferred by males. However, females preferred a combination of methods for navigation (e.g. written notes, a map, a passenger). In addition, females reported more problems with navigating in unfamiliar areas. The extent to which results of this kind have implications for the design of a route guidance system is not clear. They would suggest that females may be less able, or less

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* Some recent work by Burns (1997a) will be discussed in Chapter 4.

confident, in using a map-based navigation display, and would prefer verbal instructions. Indeed, Mashimo, Daimon and Kawashimo (1993) found some evidence that males were better able to navigate with a North-up map display than females.

Ward, Newcombe and Overton (1986) revealed gender differences with respect to the preference for landmark information. In their study 176 undergraduate students were instructed to study a map which included a scale, a variety of landmarks and compass directions, and then to provide directions for different origins and destinations on the map. They found that males used more distances and cardinal directions in their directions than did females, who placed a greater reliance on landmarks and relational terms (e.g. left/right). Although the authors did not explore directly why landmarks were chosen, they do postulate that females use cardinality less in dealing with the environment due to stylistic preferences, rather than a lack of competence in using a co-ordinate reference scheme. On the basis of these results one might expect that the presentation of landmarks by route guidance systems would lead to greater benefits, in terms of system acceptance, for females than for males, although no study has addressed this possibility.

2.5.4 *Perceptual/cognitive factors*

A driver's spatial ability is generally considered to be central to efficient navigating, at least when using current methods (Wochinger & Boehm-Davis, 1997). Streeter and Vitello (1986) used questionnaire and standardised 'paper and pencil' ability test techniques to address a number of different issues regarding people's current navigational strategies, preferences, experiences and abilities. A total of 33 female subjects were given ability tests and answered the majority of the questionnaires. However, of these only 15 female subjects were asked what constituted good and bad landmarks for navigation. They found that drivers' preferences for landmarks were sensitive to individual differences in spatial ability. Subjects who scored low on the spatial ability tests rated landmarks as more valuable for navigation than did those who scored highly, and rated most landmark types as generally good (i.e. they seemed less able to differentiate between good and poor landmarks).

The authors conclude that those with poor spatial skills rely more on landmarks for navigation than do those with high ability. No reasons are given as to why this may be so, although it is noted that individuals with *good* spatial skills expressed a greater use of spatially-based cues, for example, information within maps. A possible explanation may be that people who have poor navigational skills have a greater need for reassurance and receive this confirmation from strong visual cues such as landmarks. Indeed, self reports concerning navigational ability were found to correlate to a large degree with the objective measures of spatial ability. A similar result has been found by Kozlowski and Bryant (1979) in relation to general orientation abilities.

Although the results of this study must be treated with caution, given the small number of subjects of only one sex, they are given some substantiation by the findings of the road-based study conducted by Schraggen, 1990 (described earlier in section 2.3.2). Females made more navigational errors than males, which could be explained by their greater reliance on street names for navigating (i.e. a strategic factor). Since street name signs may be considered an example of a poor landmark, the study corroborates Streeter and Vitello's assertion that poor navigators are not able to value landmarks differentially and place an over-emphasis on such sources of information.

An individual factor which may be related to the use of particular types of information for wayfinding is perceptual style, commonly referred to as field dependence/independence. Field-independent people are better at distinguishing relevant cues from irrelevant cues in their environment than those who are field-dependent. Several studies have produced evidence that field dependent drivers are more likely to have accidents than field independent drivers (Barrett & Thornton, 1968; Harano, 1970). Goodenough (1976) believes the reasons for this, among others, are that field dependent drivers do not quickly recognise developing hazards, and are slower in responding to embedded road signs (those surrounded by many other stimuli). It may be hypothesised that these reasons would influence an individual's preference for, and use of, potentially embedded information within the environment, for example, street name signs and landmarks. Such a viewpoint has been expressed by Gould (1989).

2.5.5 *Driving/navigating experience*

There are a number of experiential factors of relevance to the use of a route guidance system:-

- experience in driving
- experience in use of a particular route guidance system/systems in general /technology in general
- experience in navigating in unfamiliar areas (in general, and particular areas)
- experience of different driving environments

With respect to information content issues, the last two of these factors are likely to be of most relevance. Unfortunately though, there appears to have been little comment regarding the implications of these factors for route guidance system design, and no identified empirical studies. Gould (1989) makes some reference to the role of experience when he notes that people who travel extensively possess considerable knowledge of use for navigation, e.g. probable layout of cities, useful landmarks. Dillon (1994), citing Brewar (1987), has referred to this general knowledge as global schemata of the environment.

2.6 Models of route guidance system use

As stated in Chapter 1, this PhD thesis is driven by a need for human factors knowledge, rather than a desire to deal with specific theories of driving and/or navigating. Nevertheless, there are three models described in the literature that are of particular interest to this PhD, since they aim to conceptualise the use of in-vehicle route guidance systems for navigating.

Wickens (1990) describes a model which aims to predict the workload imposed by navigation, and the likely error types for different kinds of navigational aids. This model is very much driven from an aerospace perspective, and thus it focuses on the users' general orientation requirements. There are three key components within the model:

- A physical representation of space (what is out there);

- The traveller's egocentric view of the world (what can be seen now);
- The traveller's mental representation of space (what is known: either a stored representation in long-term memory, or an image held in short-term memory, based on looking at a map).

The navigator can be said to be spatially oriented when there is a correspondence between the three representations. Feelings of 'lostness' arise when there is poor linkage (e.g. when the traveller's view does not correspond with what they expected to see). The model is discussed in relation to the design of map displays, and ways in which correspondence can be ensured (e.g. by using 3-dimensional displays).

The emphasis on map displays within this model is due to it being predominately based on an aviation perspective. Although the author states that research conclusions should generalise to the domain of land navigation, unfortunately no attempt is made within the paper to make this conceptual step.

Mark (1989) has proposed a conceptual model for navigating and driving, in which the following five fundamental functions of the vehicle navigation 'system' are proposed (NB - in this case the 'system' includes all "minds, machines, objects, and devices involved in navigation", p.449):-

1. The geographic database - the storage of information regarding the roads, junction layouts, landmarks en-route, etc.
2. Location of vehicle and destination
3. Route planning from the current location to the destination
4. Instruction generation - determining the specific directions that allow the driver to transverse the route
5. Control of vehicle

Mark's model is flexible, in that these functions can be allocated to different components of the system (e.g. the driver, a passenger, a map, an electronic navigational aid, a vehicle), hence describing a variety of different means of navigating. Figure 2.3 shows a summary of the functional components of the model and their interrelationships.

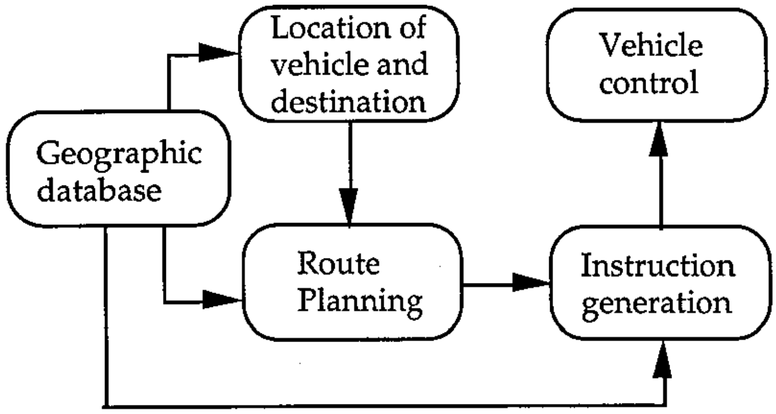

Figure 2.3 - Conceptual view of the vehicle navigation 'system' (Mark, 1989)

The usefulness of this model is that it can be applied to describe different types of navigational aid. For example, early systems such as ETAK™ performed the geographic database and vehicle location functions, whereas the driver (or passenger) had to carry out route planning, instruction generation, and vehicle control. More recent route guidance systems, such as Philips CARiN™, perform all functions of the 'vehicle navigation system', apart from the control of the vehicle.

As stated by Mark, the model can also be used when focusing on research questions, for example, which functions should be performed by human minds (driver and/or passenger), which should be assigned to the computer, and which should be assigned to traditional maps. However, as the HMI to the driver is only given a cursory place in this model, there is little indication as to how best to present information to the driver, or which information would be most appropriate.

A more elaborate model has been proposed by Zhai (1991). In contrast with Mark, his behavioural model explicitly accounts for the interactions between the driver, navigational aid, vehicle and environment. Figure 2.4 presents the model. The boxes refer to functions that are carried out (the shaded boxes are those performed by the navigational aid), whereas the circles refer to basic information sources.

The model includes the planning, decision making, control and perception tasks carried out by the driver. Navigational decisions are made on the basis of information from the outside view, the navigational aid, and the drivers' mental representation of the environment (cognitive map). In the paper the model is contrasted with a baseline model of traditional navigation whilst driving. This comparison demonstrates the difficulties of divided attention that a user of a vehicle navigation system will suffer.

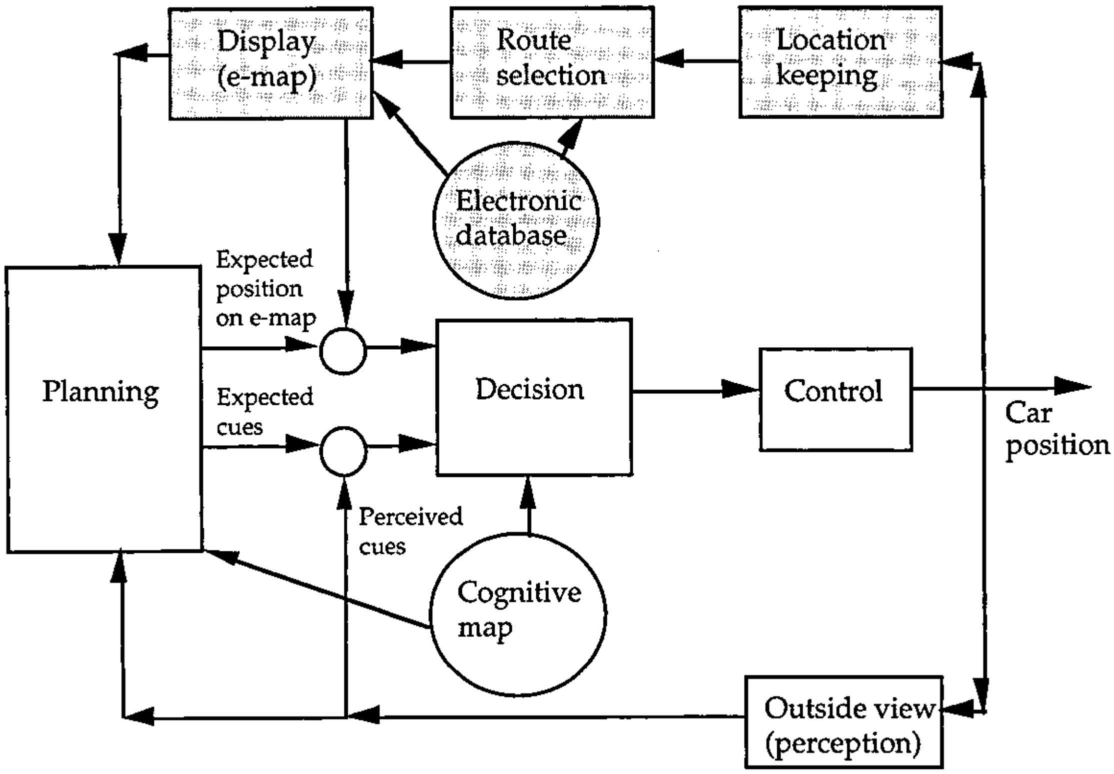

Figure 2.4 - Behavioural model of using a navigation system (Zhai, 1991)

Although this model is undoubtedly the most evolved and relevant of those in the literature, there are several limitations in its appeal:

- The model seems to relate to early map-based navigational aids. The information processing cycle for the use of simple turn-by-turn systems is notably different (e.g. planning is minimal and matching occurs relevant to a junction representation, rather than to a map view)

- The presentation of time-sharing as occurring between the in-vehicle source and outside view is simplistic. Time sharing can still effectively arise between the tasks of extracting navigation cues from the environment (e.g. landmarks, street signs) and the guidance cues required for driving. The author appears to recognise this point, but the proposed model does not reflect it.

- In its present state, the model provides little information to the reader as to its implications for interface design. This is primarily because the different information processing stages are at too high a level and have not been related to the salient characteristics of information within the environment (e.g. visibility of landmark) and within the system representation (e.g. complexity of display).

It is quite apparent from the above that there has been no satisfactory breakdown of the task of navigation. Such an exercise would enable a better understanding of how particular types of route guidance information could support different components of the driver's navigation task, and is included in Chapter 9 of this thesis.

2.7 Summary of literature review

In general terms, this literature review (including that given within Appendices 2A and 2B) illustrates the vast number of human factors issues that exist concerning the design of the HMI for in-vehicle route guidance systems. Specifically, the following summary points can be made, relevant to each of the three main headings of the review:-

2.7.1 Information content

- Many studies have made the assumption that a drivers' cognitive map is the best source of 'ideal' route guidance information. However, such a method leads to results which are wholly dependent on the area in which the study is carried out, and neglects indications from background disciplines that there are natural distortions in drivers' mental representations of the environment. Two alternative information sources have attracted only little attention in the literature: actual observation of a route; and drivers' general navigational knowledge.

- Information content studies have generally either utilised a direction giving exercise or verbal protocols as a means of extracting potential 'good' route guidance information types. There are pros and cons of each method, and it has been suggested that both methods should be used to investigate the 'content' issue fully.

- A variety of categorisation schemes have been employed when examining the content of information for route guidance systems. These are principally based on work related to cognitive maps and mapping, and are at too gross a level for easy application by system designers.

- Several studies have addressed the potential for presenting landmarks in the HMI for route guidance systems. The strongest argument for the inclusion of landmarks appears to be with respect to their impact on system acceptability, that is, subjective component of overall usability. However, some objective benefits have been revealed, and it is quite likely that the experimental set up of other studies (e.g. route complexity, number of landmarks) limited the potential of landmarks in aiding the driving and navigating tasks.

- There has been no human factors work considering the characteristics that make particular landmarks appropriate for navigation. Rather, lists of the most commonly reported landmarks have been drawn up from a sample group of drivers. This leads to results which are wholly environment, country and study specific.

- Furthermore, it must be noted that all of those studies which have made comments regarding 'good' landmarks have been non-UK based, and the applicability of their findings to this country must be questioned.

2.7.2 Presentation of particular information types

- There has been little direct work regarding how to present specific types of information to drivers (e.g. landmarks, road layout, distance to turn). If certain information is to be commonplace within route guidance systems of the future, then it will be important that standardised means of presenting such information are developed. This is particularly relevant in the case of visual icons (e.g. for landmarks).

2.7.3 Individual differences

- There are several age-related factors (perceptual and cognitive) which have implications for the HMI for route guidance systems. Although there have been some empirical studies investigating the significance of these issues, to date there has been no body of work which has established how the optimum HMI for an older driver may differ from that for a younger driver.

- There is evidence that people who perceive their navigational skills to be low will receive a greater subjective benefit from the presentation of strong visual cues (e.g. landmarks) by a route guidance system. Moreover, such individuals have been found to be poor at discriminating between good and poor landmarks.

- Its is possible that females will find a route guidance system which utilises landmarks to be more acceptable than males. Such an outcome may be explained in terms of perceived navigational abilities, since females generally do perceive their abilities to be poorer than males perceive theirs. No empirical study has addressed this issue.

- Finally, there have been claims that a driver's perceptual style (e.g. field dependence/independence) will affect his or her ability to make use of particular types of navigation information within the environment, particularly embedded information. However, no research has examined such a hypothesis in the context of route guidance system design.

Chapter 3: The problem with navigation information - Interviews with drivers

3.1 Introduction

As noted in Chapter 1, driver navigation is a complex task, requiring the use of a variety of different perceptual and cognitive mechanisms. Although there have been some general comments with respect to the current problems encountered by drivers (e.g. Petchenik, 1989; Barrow, 1991), little research seems to have focused on specific problems, particularly with respect to the use of different information (e.g. road signs, road layout, road/street names, landmarks).

Knowledge of this kind will be useful when considering the design of HMIs for route guidance systems. Many of the issues associated with navigation information are felt to be independent of the information presentation medium, for example, the relative benefits of different strategies for using information, quality of information within the environment, etc. In addition, by investigating the strategies that drivers use when navigating, an overview of the processes involved in the navigation task can be attained.

The study reported in this chapter was conceived as a means of providing an initial, realistic context to the thesis. Consequently, it was felt appropriate to conduct the study on public roads, employing an experimental design to ensure that the driver's navigation task closely resembled a real-life situation.

3.2 Aim of study

The primary aim of this road-based study, within the context of the PhD, was to identify the difficulties that drivers currently encounter when using various strategies and types of information for navigating in unfamiliar environments.

3.3 Method

3.3.1 Subjects

13 male and 6 female drivers took part in this study (mean age 39.3, SD=9.73, range 23-54). The subjects used in the study were experienced drivers - they had driven an average of 23,600 miles (SD=8,300, range 13,000 to 40,000) in the previous year and had held a driving licence for an average of 20 years (SD=9.56, range 6-35). None of the subjects had driven in the test area before.

Generally, subjects were also experienced navigators who felt themselves to be proficient in navigating. For instance, when asked to estimate the proportion of their annual mileage which was spent on unfamiliar roads, an average of 49% was reported (SD=17.3, range 30-95%). In addition, in response to the overall question, "When driving on your own in an unfamiliar area, how good are you at finding your way?", on a 9 point scale (where 1=very good, and 9=very poor), 17 of the 19 subjects gave a rating of 5 or less.

3.3.2 Test environment

The road trial took place in an urban driving area (the city of Derby in the UK) in September/October, 1995. Given the need to investigate the problems experienced by drivers when navigating, it was considered important to incorporate complex, inner-city driving situations within the routes. The Derby area was chosen (a) because the mix and type of city centre roads met these criteria, and (b) because it was easier to find subjects who had never driven in the city (many people from the Loughborough area know the road layouts of the nearby cities of Leicester and Nottingham, whereas relatively few know Derby).

To maintain maximum realism within the study, subjects were given just two addresses to drive to in succession. Specific routes were not designated and only one constraint imposed (i.e. use of Junction 25 on the nearby motorway (M1) to ensure subjects approached the first destination from the same direction). The destinations were chosen to encourage drivers to use routes which covered a variety of different driving and navigating situations. Map of the test area are shown in Appendix 3A.

3.3.3 *Procedure*

Prior to attending the session, subjects were asked to bring any materials, including maps, which they would normally use when driving and navigating in an unknown area. This even resulted in one subject arriving with a laptop computer complete with the route-finding program AutoRoute™. In addition, the following set of maps were provided in the test vehicle:

- Two street plan books (A-Z and Super Red Book)
- 1:50,000 Ordnance Survey Landranger map of the Derby area
- 1:200,000 map of the East Midlands area
- 3 miles to the inch Ordnance Survey Road Atlas of Great Britain

The experiment began at the HUSAT Research Institute in Loughborough. On arrival at HUSAT, subjects were informed that the experiment concerned the choice of routes for navigation, rather than the use of different strategies. It was felt that this approach would minimise the likelihood of idealised strategies being adopted by subjects. Subjects then drove the test vehicle for approximately 15 minutes to familiarise themselves with its controls. Having returned to HUSAT, they were shown the various maps provided and given the first written scenario shown below:

Scenario 1

We would like you to drive to a pub within Derby. To get to Derby please drive up the M1 and leave the motorway at junction 25. So that we can be sure that you get to the correct destination we would like you to note (on the provided paper) its brewery name.

You are supposed to be meeting a friend at the pub in 50 minutes from now; therefore, we would like you to aim to get to this pub in this time. Please note, getting to the destination safely is more important than getting there on time. The address of the pub is:

The Horse and Groom,
On the corner of Parker Street and Elm Street, Derby.

The subjects were also told that when they reached this first destination, they should open up the envelope provided which contained the second scenario shown below:

> **Scenario 2**
>
> We would like you to drive to another pub within Derby. Once again we would like you take a note of the name of the brewery of the pub once you have reached it. You have arranged to meet another friend at this pub, this time in 30 minutes from now - please aim to get to the pub in this time. Please note, as before, getting to the destination safely is more important than getting there on time. The address for the pub is:
>
> The Vulcan Arms,
> On the corner of Walbrook Road and Prince's Street, Pear Tree, Derby.
>
> When you have noted the brewery for this pub please drive back to HUSAT via the quickest route.

Times shown within the scenarios were based on the experimenters' experience of driving to the destinations at a representative time of the day, keeping to the speed limit and driving to the road conditions. As stated within the scenario, it was stressed again that these were target times with no pressure on drivers to achieve them at the expense of safety. Subjects were then left to plan a route and drive to the two destinations. To avoid the likely effects that an experimenter's presence would have had on naturalistic driver behaviour, subjects were **not** accompanied during the experimental phase.

On returning to HUSAT, subjects were interviewed for between half and three quarters of an hour in a semi-structured format. During this time they were shown a photocopied street plan map of the entire area (on a single sheet) and asked to talk through their experiences whilst highlighting the route they followed. This served as a useful means of structuring the interview. Specifically, subjects were asked to provide comments with respect to:

- the strategies they were employing (i.e. where within the road network were they looking to get to at different stages of the journey?)

- the information they were looking for (both within the maps/notes and out on the road)
- any difficulties encountered with their chosen strategy/information

The whole session (including the interview) took between 3 hours and 4.5 hours, dependent on traffic and difficulties encountered en-route. Subjects were paid to cover their time and out of pocket expenses.

3.4 Results/Discussion

Considerable data were generated by the interviews, and the purpose of this section is to summarise key findings and points. Full transcripts of the interviews can be found in Appendix 3B.

Given the qualitative nature of the data generated by this study, it is felt necessary to combine the results and discussion sections for this chapter. Comments have been grouped under the following main headings:

- Pre-trip planning - the level of planning carried out and the extent to which knowledge gained aided/hindered subjects during the drive.
- Strategies adopted en-route - The approaches taken by subjects during the journey in order to locate specific decision points.
- The role of global knowledge - the influence of drivers' previous knowledge in making specific decisions during the journey.
- Information within maps - examples where the specific information contained within maps either enhanced or reduced drivers abilities to find turnings en-route.
- Information within the environment - examples where characteristics of the information within the environment (e.g. street names, road signs) affected drivers' abilities to find turnings en-route.
- Use of passers-by - detailing instances where drivers called upon assistance from pedestrians, the information given, and the usefulness of that information.

3.4.1 Pre-trip planning

The majority of the subjects used in this experiment formulated an overall plan before setting off based purely on consulting the maps provided. Two subjects made some reference to the maps that they had brought with them. Only four subjects made any notes based on their planning, and instead subjects preferred to commit their plans to memory. For those subjects who did make notes, the primary information contained within them consisted of key road numbers and names, and during the interviews subjects stated that they wrote this information down in case they forgot it whilst on the journey.

This result seems to be in conflict with those of Parkes and Martell (1990) and Streff and Wallace (1993) who found in their surveys of drivers that the majority report the use of written notes for navigation in urban areas. Although differences in the subject populations may be partly to blame, it is felt that the result also reflects the differences between reported and actual behaviour. Given a realistic scenario with an element of time pressure, it is quite likely that many drivers will make few written plans, and instead place an emphasis on the use of their memory/road signs to find their way.

In specific terms, it was possible, based on the interviews, to establish the following list of the basic information contained within the pre-trip plans made by drivers. In most cases, this information was committed to memory. Drivers varied in the number of different items contained within their specific plan.

- The name of the destination area/neighbourhood.
- The direction of the destination in relation to the driver's origin (i.e. their starting point). In most cases, a global reference scheme (e.g. north-east wards) was used for this information.
- The direction of the destination in relation to key points (e.g. particular roads/junctions) that the driver aimed to reach en-route. In these cases, an ego-centred reference scheme was used (e.g. over to the right).
- Arrangement of main roads going into the city centre (i.e. the basic spatial layout of roads in the area).

- Key strategic roads (usually main A roads) and their labels (numbers/ names), e.g. roads which ran close to the destination area.
- The nature of the roads both in the destination area, and on the approach to that area (e.g. main, residential, one-way).
- Characteristics of key junctions in the area/en-route (i.e. their type, complexity, size, names, etc.).
- Distinctive landmarks in the area, particularly those which were likely to be signposted (e.g. hospital, railway station, football ground, river), and were close to the strategic roads above.
- An idea of scale - in some instances, this was used to calculate approximate driving distances/times required along particular key roads before a decision was likely to be required.

It was apparent from drivers' comments that pre-trip plans of this kind were primarily intended to give a useful overview of the area surrounding the destination, and thus were of use for general orientation purposes (i.e. a sense of position in relation to destination or destination area). Furthermore, it was evident that drivers' plans, in most cases, were designed to get them to the destination area, rather than the actual destination. Many subjects reported that they intended to stop when close to the destination and plan the final stage of the journey.

Nevertheless, considerable difficulties arose when drivers placed a reliance on their overall plan to guide specific decisions regarding turnings en-route. For example, inappropriate lane choices arose when subjects relied on general knowledge of the relative position of the destination (e.g. "In my mind's eye I needed to get over to the right") to make a specific turning decision. Furthermore, navigational errors (turning off the road too early or too late) occurred due to subjects misjudging the distance they had travelled along the road. Not surprisingly, such high levels of navigational uncertainty were reflected by confusion on the part of some subjects in verbalising the route that they took.

3.4.2 Strategies adopted en-route

In most cases, the strategies adopted en-route to deal with navigating on major roads were developed during pre-trip planning. Often, this involved an attempt to find the inner city Ring Road, and then, as noted by one subject, "to stay on this road at all costs", until a road sign was spotted that was likely to lead the driver closer to the destination area.

With respect to the different information sought whilst on these roads, subjects generally had greater confidence in using road numbers, whereas place names, compass directions (e.g. North, South) and references to landmarks were considered to be supplemental and hence given a lower priority. The likelihood of road numbers appearing on actual road signs was considered by subjects to be the dominant factor here.

It was evident during the interviews that drivers aimed to get an overview of the appearance of the next manoeuvre (either during pre-trip or en-route planning) to assist them in identifying it at a later point. This was particularly the case when travelling on urban roads. The type of junction (e.g. roundabout, slip road, X-roads), relative sizes of junctions, and any distinctive features (e.g. sharp angles, fork) were all reported as information contained within this overview.

The situation was markedly different in out of town driving and on residential roads. In these cases, drivers made relatively little attempt to gain an overview, although the 'end of the road' was often used to indicate a T-junction. Nevertheless, a combination of (a) counting streets/roundabouts (e.g. 3rd on left, right at 2nd roundabout) and (b) looking for street names was the dominant strategy on these roads.

The use of a counting strategy rather than looking for street names differed between drivers and between situations. For instance, counting turnings was considered by some to be too difficult when there were many turnings prior to the required manoeuvre, and instead many drivers would prefer to search for the desired street name at each turning. To assist them in this, several drivers adopted the strategy of remembering the street name prior to the one they required. As remarked by one subject, "normally I note other streets (at least 1 or 2 of the roads before actual) - this allows me to prepare so I don't suddenly end up on top of junction". A few subjects had also noted that many of the street names within one of the destination areas were all boys' names (e.g. Douglas street, Leopold Avenue). As a result, when a street with a boy's name was observed, they were confident that they were close to their turning.

Drivers in this study made relatively little use of landmarks, most likely due to the limited number available within maps and/or the difficulties in knowing how suitable they are for navigation, based on a map representation. As a result, on the whole, drivers chose more 'strategic' landmarks which were (a) close to the destination area or a key road, and (b) likely to be included on road signs. Examples of such landmarks included the city hospital, railway/bus station, parks, and theatre.

3.4.3 The role of global knowledge

There were many instances where drivers' previous knowledge, developed through experience, affected navigational performance. One key factor concerned the likely form that oncoming roads and junctions would take. For instance, it was considered that the difference between main and minor roads served as a powerful cue for navigation, and several characteristics were looked for (e.g. the amount of traffic, the speeds of vehicles, the presence of traffic lights, the size/shape of the junction). It was also reported that the second destination was within a radial network which meant that one could take any turning and get relatively close to the destination.

As stated in the previous section, many of the subjects were attempting to get into the city centre prior to making any specific decisions. Several relative characteristics of the environment were reported which informed the subjects that they were within/close to the centre (e.g. increased traffic, more buildings/bigger buildings, more junctions/decision points), as well as information on road signs.

Prior knowledge of the position of surrounding towns and place name/road number associations affected what information was expected on road signs. As an example, when travelling across Derby to find the second destination, many subjects were actively searching for road signs which contained the names of places they knew to be south of the city.

Subjects also reported that a number of known features of a landmark could inform them that they had reached that landmark. For instance, although several subjects did not see the sign for a park, they were well aware that they were passing it (due to an increase in the number of trees and proportion of open, green space in relation to what had just been passed, children's play equipment, etc.). In a similar fashion, a parapet by the side of the road led many subjects to suspect they were crossing the river landmark, even when the river itself was not actually seen.

3.4.4 Information within maps

Although the interviews typically focused on the problems encountered, there were several positive comments made by subjects regarding the information contained within maps. For instance, it was believed that the coding employed within maps (e.g. via colour and size) helped drivers in many situations to establish the relative size of turnings. This was of importance when deciding which of the numerous side roads would be major versus minor, and whether roads might be one-way. The relative complexity of junctions was also apparent from the maps provided (e.g. a roundabout seen as a major one by its enhanced size on the map).

In addition, there were several instances where particular types of information presented by the maps significantly aided the drivers in finding a desired decision point or the final destination. For example, one driver had noticed that the destination was close to a small roundabout, and this became an important 'landmark' for him. Furthermore, another driver was aware that she had to turn off the main road just after the road changed from dual to single carriageway (shown on the map), and, as a result, successfully carried out the manoeuvre. The distinctive shapes of particular junctions (as shown within the maps), e.g. forks, or 'dog legs', were also considered by some to aid navigational decision making.

The problems experienced by drivers in this study in using the information contained within maps can be broken down into the following main headings. Examples of each heading are discussed below.

(1) Driver not noticing relevant information which *was* included on the map(s)

(2) Driver not seeing relevant information, because it *wasn't* on the map(s)

(3) Driver misinterpreting the road layout on the map(s)

With respect to (1), several drivers mentioned that they did not notice dead ends or the linkage of roads around the first destination. As a result, many found it difficult to reach this destination. Particular junctions (e.g. relevant side turnings) were also missed, as well as pertinent street name changes which led to misconceptions over current position along roads.

In certain cases, street names were stretched along a road on the map (i.e. widely separated letters), and several drivers reported that they had not seen the name. In addition, as drivers had to travel across several pages of the 'A-Z' map, the transfer from one page of a particular scale to another with a more detailed scale, confused many subjects, and led to some gross misunderstandings with respect to current location.

With respect to (2), the maps used did not inform the subjects of the following desired information, although it must be noted that in some cases this was because the driver was not using the most appropriate map:-

- Forbidden turns (e.g. no right turns).
- One-way streets.
- Particular roads/junctions.
- New roads/junctions - for one particular area where an industrial estate had recently been built, there were several new roundabouts, leading to considerable confusion.

There were also instances where roads/junctions were obscured (either by reference circles, the fold on map, or by names of proximate landmarks).

Concerning (3), misinterpretations were most prevalent for complex junctions, where drivers mentally allocated a junction to the wrong type (e.g. perceiving a slip road to be a right turn, or a flyover to be a roundabout). The coding of different roads and junctions described by some to be a positive feature of maps was considered by others to be misleading. For instance, different relative widths of road within the map were not reflected when on the road. Shapes of complex junctions were also inaccurately perceived, for example, "2nd exit on roundabout seeming like left on ground, but was straight on for map - junction seemed more twisted on the ground".

3.4.5 Information within the environment

In agreement with the results found by Schraggen (1990), it was evident that many of the drivers who took part in this study placed considerable reliance on the use of road/street names for navigation, and this strategy was associated with poor navigational performance. With respect to specific difficulties encountered, there were numerous reported incidents where drivers did not see the street name they were looking for, or didn't see the street name until they were already committed to a manoeuvre and it was too late to change course. In the latter case, the belated viewing of the street name was noted by some to serve as valuable confirmatory information.

With respect to the use of road signs (containing information such as road numbers, place names, compass directions, and points of interest/ landmarks), the central problem encountered by subjects was not one of seeing the sign. Signs of this kind within the UK are generally designed to be highly visible for drivers (Jeffrey, 1981). The principal problem was of sought after information not being present on the sign, a situation which was particularly the case for bracketed road numbers (whereby strategic routes to a particular road are given) and place names. For such information, it was evident from the interviews that drivers found it difficult to predict what exactly is likely to be on given road signs based on the use of paper maps.

3.4.6 Use of passers-by

Three of the nineteen drivers made use of passers by for information to help them find their way. Analysis of these subjects' comments provides some interesting background knowledge regarding current navigational strategies, particularly with respect to the social aspect of direction giving and receiving.

One subject made extensive use of passers by. Indeed, in the interview he expressed considerable frustration from his experience of obtaining directions from passers-by, and estimated that he asked fifteen people how to reach the first destination. One reason he felt he had to ask so many people concerned the area within which he found himself lost. Unfortunately, he was close to Derby University and many of the passers-by were first year undergraduates in their first week of study who knew little about their surroundings. This male subject also experienced difficulties in obtaining any form of reply from two female pedestrians. As a direct consequence of such difficulties, the driver stated that during the second journey he only asked men who looked as if they were locals.

A further subject stopped to ask a passer-by how to find a particular road, and was told to "just drive around the one-way system and you'll see it". This driver did not feel this advice was clear and, as a consequence he had to re-examine the map prior to setting off.

The third subject commented that he was "getting a little desperate", since he had passed a lot of turnings, but had been unable to locate the particular road he was looking for. Therefore, he stopped and asked an elderly couple who he felt were likely to be locals. Their reply was that they had never heard of it. The driver then asked about a different road, one which was key to his overall plan. The couple knew of this road, but were unsure whether the driver might actually want a different road with a similar name. Following some discussion in which the map was examined by all parties, they provided him with directions to the original road, "turn right at first roundabout, then right at next, then under a spider bridge and Omaston Road would then be apparent". The driver felt these instructions were useful, although he admits that he did not actually know what a spider bridge was. Nevertheless, when travelling it was apparent to this driver which bridge the couple were referring to.

3.5 Conclusions/design implications

- The study served as a useful means of highlighting many of the difficulties experienced by drivers when attempting to find their way in unfamiliar surroundings. In general terms, the work supports the need for improved means of navigating (as expressed in Chapter 1). Many drivers in this study experienced considerable difficulties in locating the destinations, reflected by the fact that only three of the nineteen subjects reached both destinations within the specified time limits. Furthermore, although not reported here*, it is sufficient to say that a large number of instances of poor driving behaviour (e.g. lack of attention to other road users, misleading use of indicators, irregular speed control) occurred as a direct result of the overhead of the navigation task.

- With respect to design implications, the results showed a number of instances where an overall view (i.e. a mental representation of the route and the surrounding roads) was extremely influential in specific navigational decision making (i.e. which turn to make). The list of the information included in drivers' overall plans, as generated by this study (section 3.4.1), gives an idea of the range of information that may be appropriate for presentation within a route guidance system (most likely via a map, accessible prior to setting off).

- Furthermore, it is clear from the interviews that drivers' previous experience and expectancy as regards the environment is a major contributing factor to navigating behaviour and performance. This includes situations where expectancy with regards to the layout of the road, junctions and surrounding environment either enhanced or seriously degraded performance. It will be important that the HMI for a route guidance system positively 'draws on' such expectancies, for example, by informing the driver either directly or indirectly of a main road versus a minor road, the approach to a city centre, or the appearance of key landmarks.

- The study revealed a large number of difficulties experienced in using maps for navigation, illustrating the importance of well designed map displays for route guidance systems. For instance, the presented layout of complex junctions (e.g. roundabouts, slip roads) within maps was misinterpreted by several subjects. Furthermore, subjects were not always able to see relevant information on the maps, which was either present (e.g. the linkage of roads in residential areas, street name changes, information that went across different pages), or was not

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* Objective measures of driver behaviour were captured as part of the consultancy aspect of this project, and thus are confidential to the client.

actually present (but would have been of use), e.g. forbidden turns, one-way streets, and new roads/junctions. This latter example highlights the need for frequent up-dating of digitised maps.

- Many of the problems experienced by drivers in this study would be alleviated or indeed removed via the use of a well designed, accurate, timely route guidance system. However, the study also revealed difficulties with respect to the use of road side information (road signs, street names and landmarks), and some of these problems may still remain if a route guidance system refers to this information within its HMI. For instance, many drivers did not find the information which they were looking for within the environment. This result was especially evident with regard to street names which were used extensively and with mixed success by the subjects. The poor predictability of road sign information was also a major problem for drivers, illustrating the fundamental requirement for a knowledge link between a route guidance system and the existing navigational infrastructure.

Following on from this last point in particular, the next chapter of the thesis will address the preferences that drivers have for specific types of navigation information, and the reasons behind such preferences.

Chapter 4: A survey of drivers' preferences for navigation information

4.1 Introduction

As discussed in Chapter 2, surveys are considered a useful means of drawing on the extensive knowledge that drivers have regarding the relative merits of information for navigating purposes. However, a finding of the literature review was that there have been few surveys of drivers' navigating behaviour*. Furthermore, studies have been primarily interested in overall strategies, rather than the information being used (e.g. Parkes & Martell, 1990; Streff & Wallace, 1993). As a result, there has often been a confounding of strategy, information source and information type (e.g. the comparison of "following road signs" with "using maps").

A further finding of the literature review was that a number of individual differences are likely to have an effect on the suitability of different information types, although there have been few directly related studies. Two factors of particular interest are driver age and gender.

As a first step towards gaining some specific knowledge on these topics, it was decided to conduct a basic survey of drivers' preferences for different types of navigation information. The results provided here form a subsection of those from a larger questionnaire administered as part of a project undertaken by the HUSAT Research Institute on behalf of a major car company. The full questionnaire addressed a large number of issues concerning strategies for navigating, of which only a few sections were relevant to the current thesis.

* Although Burns (1997a , 1997b) has recently conducted an extensive postal survey of 1184 UK drivers - comparisons are made in the discussion section.

4.2 Aims

From the perspective of the thesis, the primary aim of this study was to establish drivers' preferences for different types of navigation information when driving in unfamiliar areas. In addition, the study aimed to identify some basic reasons as to why certain information types are preferred over others, and to explore individual differences related to age and gender.

4.3 Method

4.3.1 Subjects

Choice

This study focused on the navigational behaviour of people who drive a greater than average annual mileage. The rationale for this decision was that such individuals would be more likely to travel on unfamiliar journeys, and hence require or make use of an electronic route guidance system. Overall mileage was used as the criterion, rather than mileage within unfamiliar areas, since it was felt that it would be easier to obtain reliable data from drivers using this parameter. The Department of Transport has calculated that the average mileage for drivers in the UK is 10,000 miles per year (Department of Transport, 1995a), and so this figure was chosen as a cut off point for inclusion in the study. It was anticipated that this requirement was likely to lead to a greater percentage of males than females being recruited for the study.

Recruitment

The majority of subjects were recruited via letter drops on the windscreens of cars in local shopping centre car parks during weekends. Letter drops at this time were used as a way of attracting a large number of working people, from which a selection could be made of those who drove a greater than average mileage. The letter advertised the work by emphasising its relevance to the development of new technology, rather than drivers' navigational strategies per se. HUSAT's subject database was used to augment the subject numbers.

4.3.2 Design of the questionnaire

The questionnaire was piloted prior to the data collection phase by ten human factors researchers from the HUSAT Research Institute, and the questionnaire progressed through several iterations. The sections of the final questionnaire referred to in this chapter are included in Appendix 4A. Specifically, three particular styles of question were set:

(A) A specific, direct question was asked, regarding the perceived usefulness of different types of navigation information, that is, "... how useful are the following types of navigation information in helping you to find your way?" It was realised that the role of environmental variability was critical to this issue, so drivers were asked this question in relation to travel on three fundamentally different road types: dual carriageways and motorways; single carriageway roads (out of towns and cities), i.e. rural roads; and roads within towns and cities, i.e. urban roads.

(B) A specific, direct question was asked, regarding the perceived effectiveness of different types of landmarks (e.g. petrol stations, pubs, traffic lights), that is, " ... how good are the following landmarks at helping you to find your way?". A total of 29 landmarks were rated by all subjects. These landmarks were obtained by asking a separate sample of 25 human factors specialists to compile a list of landmarks they considered to be of use in the navigation task. A total of over 50 different landmarks were offered. Since some were relatively obscure and it was impractical to ask subjects to rate all of the landmarks, cumulative frequencies were plotted and the 90th percentile used as a cut off to produce a final sample of 29.

(C) An indirect, context-driven question was asked. This involved showing subjects eight different styles of hand-written and sketched directions, and asking them to rank them in order of preference. An urban driving situation was chosen, as the difficulties of navigating are more pronounced in this environment, and two dimensions were given to the directions: presentation format (verbal, i.e. written, and spatial, i.e. sketched map); and information types (either landmark, road layout, distance, or road/street sign dominated). An attempt was made to ensure that the amount of information contained within the different styles of directions was comparable.

It was felt that the underlying reasons for drivers' preferences would best be generated via this last question, that is, in the context of an everyday navigation-related task. As a result, as part of the questionnaire, subjects were instructed to explain their choices on an accompanying blank sheet. This open-ended strategy was chosen in order to generate as wide a range of comments as possible from the subjects.

The questions set in parts A and B utilised nine point scales with semantic anchoring. This method was used as a compromise solution to enable easy coding of results, whilst providing some confidence in the validity of using parametric tests (with increased statistical powers).

4.3.3 Procedure

Each subject attended one of a number of sessions held at HUSAT during which they completed a questionnaire addressing a range of issues on the subject of traditional navigation. The sessions were primarily held in the evening, with between ten and fifteen subjects attending each. During an introductory briefing, the subjects were told about the aims of the study, and were assured that any responses given would be totally confidential.

The full questionnaire consisted of eight sections, and took approximately one hour to complete. This chapter concentrates on the results obtained from two sections, and reports data, where relevant, from three further sections, concerning subject details, navigating experience and perceived navigational abilities.

To ensure the experimenter had some control over the proceedings, the subjects completed two sections of the questionnaire at a time. On completion of each set of two sections the experimenter collected them in; these were then checked for gross oversights (e.g. a page left unanswered) whilst the next two sections were completed. This procedure continued until all sections of the questionnaire had been completed. Unfortunately, due to time constraints, it was not possible to check questionnaire sections in detail, and inevitably there were some missing data.

Subjects were paid to cover their time and any out of pocket expenses.

4.3.3 *Data analysis*

Descriptive statistics

The purpose of the descriptive statistics included in this chapter is to outline the basic findings of the questionnaire. The data within questions A and B were assumed to be at the interval level, and, therefore, mean values were calculated for each of the questions to provide an indication of central tendency. As a further measure of the relative preference of subjects for one option over another, percentage figures were also calculated, e.g. the percentage of subjects who answered '1, 2, or 3' from the nine point scale. Question C provided ranked data, and to give an indication of driver preferences, the percentages of subjects who ranked direction styles as either 1st/2nd, 3rd/4th etc. were given.

A large number of comments were made by subjects regarding their preference for the different styles of direction. Comments were broken down into those which were positive in nature, and those which were negative. Unfortunately, due to the open-ended nature of this question, many comments were either general in nature (e.g. "these directions are clear"), just confirmed what the directions were (e.g. "I like maps with landmarks"), or concerned the perceived amount of information contained within the directions (e.g. "these directions are very vague"). Nevertheless, many comments were specific, and it was possible to differentiate between those that were relevant to each of the information types (e.g. "landmarks help me to stay on course", or, "I can forget when counting turnings"), and those relevant to the format of information presentation (e.g. "I find it easy to look at maps on the move").

Individual differences

The primary focus of this study concerned the information requirements of drivers who are likely to have a requirement for the use of a navigational aid. Thus no attempt was made to recruit a cross section of drivers across different ages and split 50:50 by gender. As a result the sample was rather homogenous in terms of age, and was biased towards males (see section 4.4.1).

To enable some limited gender comparisons to be made, whilst balancing for age, several males were discluded from the analysis, so that an even number of subjects were present in each sex category. The removal process was carried out randomly within age groups to ensure age was matched across the male and female groups.

With respect to age comparisons, the limited number of female subjects (particularly older females) meant that it was only possible to compare the results for male subjects. Three age groups were compared: 25 and younger; 26-54; and 55 and older. In the literature, studies vary in the cut off age beyond which drivers are considered to be 'older' (c.f. Hulse, Dingus, McGehee & Fleischman, 1995 with Graham & Mitchell, 1997). However, the age 55 is generally considered to the point at which declines in both perceptual and cognitive abilities are apparent (Yanik, 1989).

As such a large number of subjects fell into the middle age bracket, it was necessary to randomly remove subjects from that group until the numbers were comparable with those in the younger and older groups (see section 4.5.1).

To demonstrate clearly the extent of differences, histograms are often used. These show the distribution of ratings and rankings within gender and age groups, e.g. the percentage of subjects within a gender or age group who answered '1, 2 or 3', '4, 5 or 6', or '7, 8 or 9' from the 9 point scale.

Statistical testing

The rating scale data (questions A and B) were assumed to be interval in level, and therefore the following parametric tests were carried out, utilising the software program, StatView™ for the Macintosh™:

- Gender differences (two unrelated groups) - t test
- Age differences (three unrelated groups) - ANOVA followed by Fishers PSLD post-hoc test

Question C was ordinal in level (ranked data), and thus the following non-parametric tests were carried out:

- Gender differences (two unrelated groups) - Mann Whitney U test
- Age differences (three unrelated groups) - Kruskal Wallis test

4.4 Results

4.4.1 General details of the subject population

Whole subject population

In total, 149 male and 51 female drivers, mean age 38 years (SD=11.7, range 19 to 75), participated in the study. They had held driving licences for an average of 19 years (SD=10.9, range 2 to 58), drove an average of 6.4 days a week (SD=1.0, range 2 to 7), and had driven an average of 16,670 miles during the previous 12 months (SD=8,710, range 10,000 to 100,000).

On average, subjects made 42 unfamiliar journeys a year (about three a month), of which 19 were for work purposes, 13 were for non-work routine purposes and 10 were for leisure purposes. Nearly 20% of subjects made at least one work-related journey per week within unfamiliar areas.

Those subjects taking part in the study generally regarded themselves as good at navigating, either for themselves or for others. They also felt themselves to be competent in using maps.

Gender differences

For the purposes of making gender comparisons, the reduced sample was as follows:

- Female: N=51; Mean age 35.7, SD=10.75, Range 20-57
- Male: N=51; Mean age 36.3. SD=9.94, Range 21-57

Comparing these two groups revealed that males had driven significantly more miles (mean 17,700) than females (mean 13,400), $t(100)=2.94$; $p<0.005$. This additional mileage could be largely attributed to increased driving on faster roads - males stated that a greater proportion of their annual mileage was spent on motorways/ dual carriageways (mean 48.3%), than did females (mean 34.8%, $t(100)=3.10$; $p<0.005$).

Proportionately more of the male drivers' annual mileage (mean 17.3%) was spent on unfamiliar roads (without a passenger), than was the case for females (mean 12.1%, $t(100)=2.13$; $p<0.05$. Further analysis revealed that this additional mileage could be attributed to work-related journeys - males made more unfamiliar journeys as part of their work than did females, $t(100)=-2.48$; $p<0.05$. There were no gender differences for other journey types.

Females generally felt their navigational abilities to be lower than did males. For example, in response to the overall question, "When driving on your own in an unfamiliar area, how good are you at finding your way?", on a 9 point scale female drivers rated their abilities (mean 4.8) to be poorer than did males (mean 3.2), $t(100)=-3.77$; $p<0.0005$.

Age differences

As stated above, only males were included in this analysis. The reduced sample was as follows:

- 25 and younger: N=19; mean age 22.9, SD=1.87
- 26 to 54: N=20; mean age = 39.5, SD=7.90
- 55 and older: N=17; mean age 60.4, SD=5.42

There was a trend for older subjects (mean mileage 13,400), and to a lesser extent the younger subjects (mean mileage 17,900), to drive less miles per year than subjects in the middle age group (mean mileage 23,400, $F(2, 53)=2.69$; $p=0.08$). This result can be partly explained by the fact that those subjects who were older than 55 reported that they made less unfamiliar journeys as part of their work than did those in the 17-25 and 26-54 age groups ($F(2,52)=3.81$; $p<0.05$).

4.4.2 Usefulness of navigation information

Table 4.1 shows the results of question A, regarding the perceived usefulness of different types of navigation information. As stated in section 4.3.2, the question was asked in relation to different road types. The figures refer to the mean score, and the percentage of subjects (in brackets) who answered '1, 2, or 3' from the nine point scale (where 1 = very useful, and 9 = useless). The figures in bold and underlined refer to the best three information types with respect to their perceived usefulness for each of the different driving environments.

	Dual carriageways and motorways	**Single carriageway roads (out of towns and cities)**	**Roads within towns and cities**
Road numbers (e.g. A417)	1.7 (93%)	1.8 (89%)	3.6 (59%)
Place names (e.g. Loughborough)	1.8 (93%)	1.8 (95%)	3.1 (66%)
Junction numbers (e.g. junction 3)	1.5 (96%)	N/A	N/A
Road/street names (e.g. Park Drive)	3.4 (61%)	2.6 (73%)	2.0 (90%)
Landmarks (e.g. traffic lights)	3.1 (66%)	2.7 (72%)	2.0 (88%)
Road/junction layout (e.g. T-junctions)	3.3 (59%)	3.0 (67%)	2.4 (82%)
Long distances (e.g. 3 miles)	4.2 (42%)	4.3 (44%)	5.1 (29%)
Short distances (e.g. 300 metres)	4.1 (50%)	3.8 (51%)	3.2 (69%)
Compass directions (e.g. North)	6.6 (13%)	6.9 (10%)	7.4 (6%)

Table 4.1 - Preferences for different information types

Gender - Females considered landmarks to be more useful for navigation than did males. This result was found for all three road types, and was strongest for urban roads, (Female mean = 1.3; Male mean = 2.4, $t(95)=2.51$; $p<0.05$), as shown by the histogram in Figure 4.1.

There was also a trend for males to consider compass directions to be more useful than did females. This was closest to significance for single carriageway roads (out of towns and cities): Male mean 6.2; Female mean 7.7 - $t(96)=-1.85$; $p=0.076$.

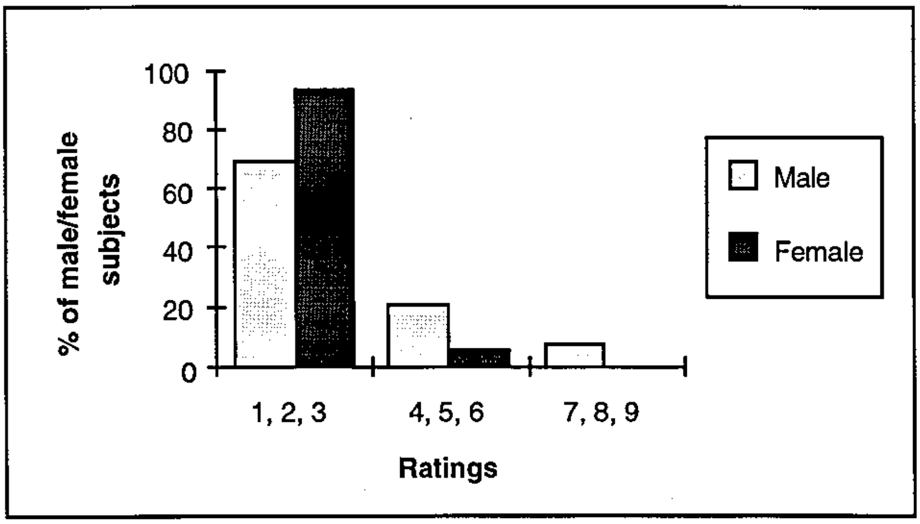


Figure 4.1 - Perceived usefulness of landmarks: roads within towns and cities - Gender differences

Age - The ANOVA tests revealed main effects for age for several of the information types. Observation of mean values showed a consistent trend for older subjects to rate the different information types as more useful for navigation than did younger subjects. This effect was strongest for dual carriageways/motorways and single carriageway roads (out of towns and cities). The following histogram (Figure 4.2) provides an example of the extent of these differences for compass directions on rural roads: $F(2, 50)=3.20$; $p<0.05$

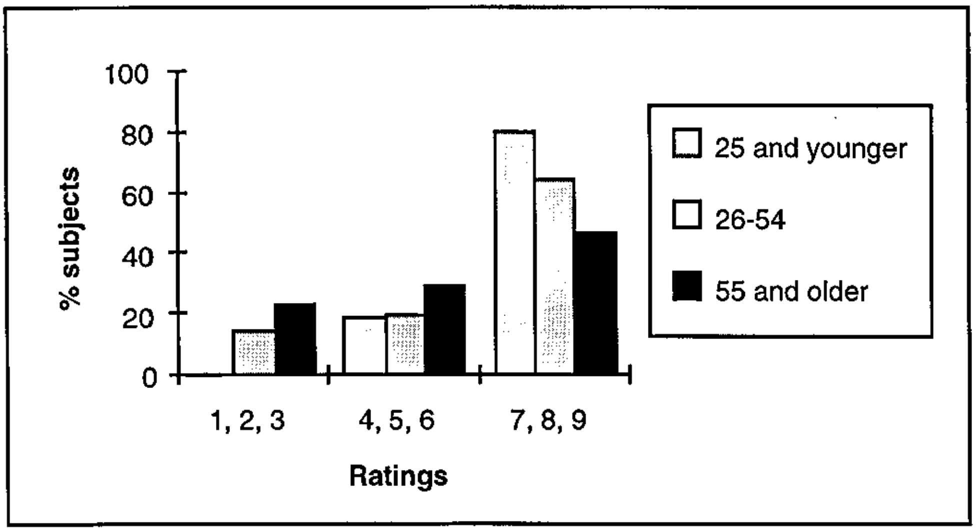


Figure 4.2 - Perceived usefulness of compass directions: single carriageway roads (out of towns and cities) - Age differences

4.4.3 *Effectiveness of different landmarks*

Table 4.2 shows the perceived effectiveness of different types of landmark, based on question B. The figures refer to the mean score, and the percentage of subjects (in brackets) who answered '1, 2, or 3' from the nine point scale (where 1 = very good, and 9 = very poor). The landmarks are placed in order, based on the percentage figures.

Landmark	Mean Scores	% '1, 2, 3'	Landmark	Mean Scores	% '1, 2, 3'
Superstore	2.4	86	River	3.4	60
Public House	2.3	84	School	3.4	57
Railway station	2.6	80	Petrol station	3.5	57
Street name signs	2.7	75	Telephone box	4.6	49
Traffic lights	2.8	74	Multi-storey car park	3.9	45
Railway line	3.1	71	Park	4.1	38
Hump-backed bridge	3.1	69	Pelican crossing	4.4	38
Cinema	3.5	69	Repairs garage	4.8	31
Bridge over road	3.2	66	Post-box	5.5	22
Shop/restaurant	3.6	66	Wood/forest	5.3	18
Church	3.0	64	Brow of a hill	5.7	18
Monument	3.2	61	Bend in road	5.7	17
Factory	3.3	61	Advertising hoarding	6.2	14
Bus/coach station	3.4	61	Dip in road	6.4	11
			Bus stop	6.1	9

Table 4.2 - Preferences for different landmarks

Gender - There was a consistent trend for females to consider each landmark as better for navigation than did males. This reached significance for the following 10 (from 29) landmarks: Shop/restaurant, Park, Wood/Forest, Bus/Coach station, Railway station, Superstore, Monument, Cinema, Advertising Hoarding and Traffic lights (p ranging from <0.005 to <0.05). The histogram below (Figure 4.3) shows the extent of these differences for the 'Park' landmark: $t(99)=3.19$; $p<0.005$.

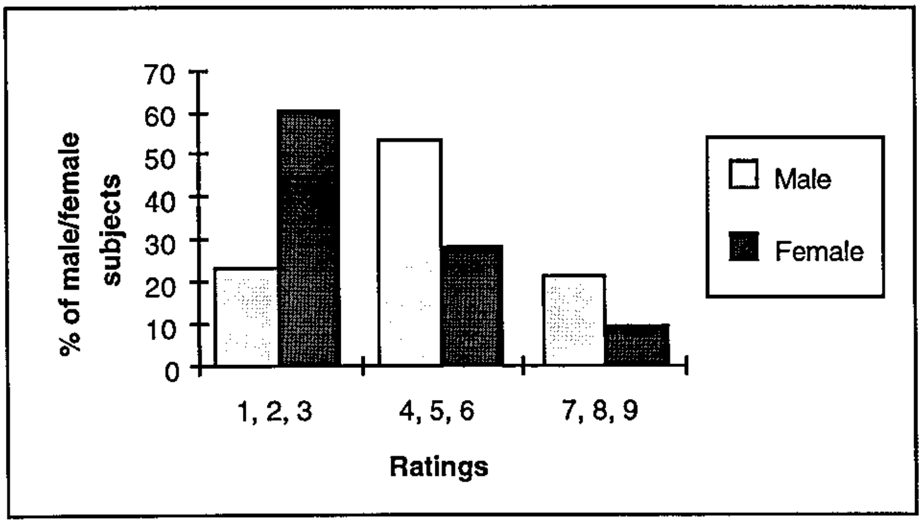


Figure 4.3 - Perceived effectiveness of the 'Park' landmark - Gender differences

Age - The ANOVA tests revealed main effects for age for several of the landmarks. Observation of mean values showed a consistent trend for older subjects to rate each landmark as better for navigation than did younger subjects. This reached significance for the following 12 (from 29) landmarks: River, Dip in road, Hump-backed bridge, Church, Cinema, Bus/Coach station, Multi-storey car park, Bridge over road, Railway station, Monument, Advertising Hoarding and Park (p ranging from <0.005 to <0.05). The following example histogram (Figure 4.4) reflects the extent of these differences for the 'Church' landmark: $F(2, 53)=6.90; p<0.005$

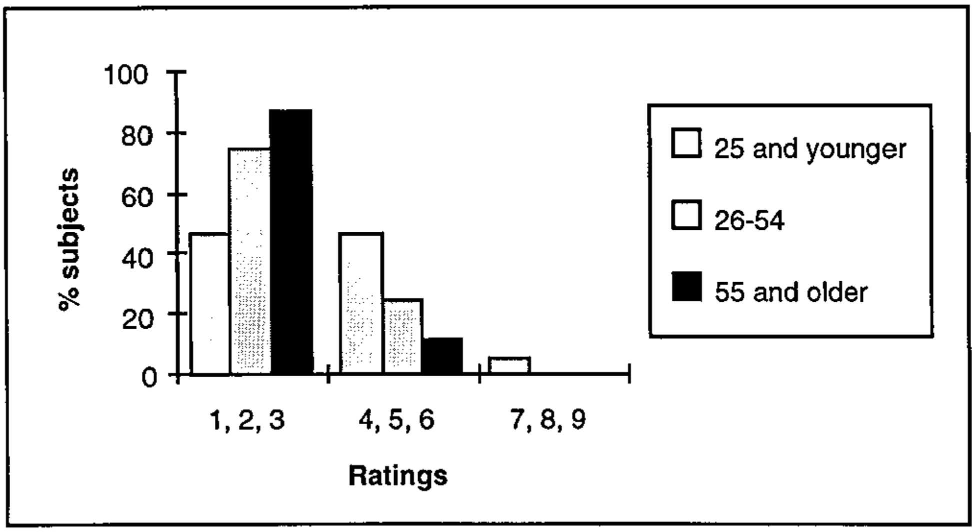


Figure 4.4 - Perceived effectiveness of the ''Church' landmark - Age differences

4.4.4 *Preference for different styles of directions*

Table 4.3 shows the results for question C, regarding subjects' preferences for different styles of directions. The figures refer to the percentage of subjects who gave a 1st/2nd, 3rd/4th etc. ranking, and the styles of directions are placed in order based on the 1st/2nd percentage value.

	1st 2nd	**3rd 4th**	**5th 6th**	**7th 8th**
Sketched map - with landmarks	56.5%	23%	15.5%	5%
Sketched map - with road/street signs	33.5%	31%	23%	10.5%
Written instructions - with road/street signs	28.5%	32%	31.5%	8%
Written instructions - with landmarks	25%	28%	23%	24%
Sketched map - with distances	23.5%	23.5%	30%	23%
Written instructions - with road layout	18.5%	22.5%	30%	29%
Written instructions - with distances	7.5%	20.5%	30.5%	41.5%
Sketched map - with road layout	4.5%	21%	15.5%	59%

Table 4.3 - Preferences for different styles of directions

Gender - There was a general trend for females to prefer all of the 'instructions' styles of directions more than did the males. This reached significance for instructions with landmarks ($Z=-2.74$; $p<0.01$), and instructions with road layout ($Z=-1.91$; $p<0.05$).

In contrast, there was a general trend for males to prefer all of the 'sketches' styles of instructions more so than did females. This only reached significance for sketches with distances ($Z=-2.58$; $p<0.01$).

The extent of differences for the first of these gender results (instructions with landmarks) are shown by the following histogram (Figure 4.5).

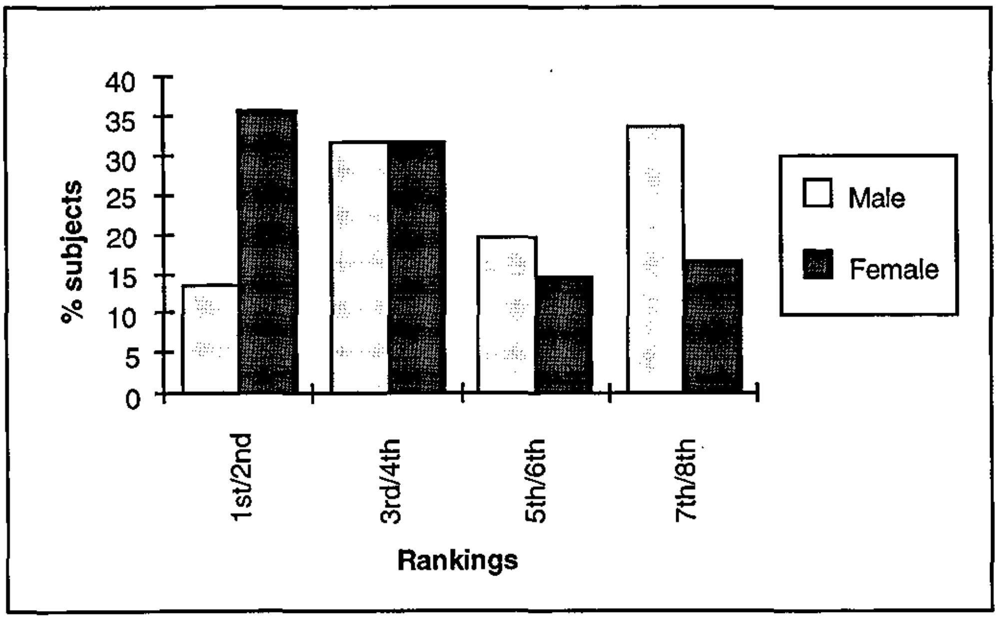


Figure 4.5 - Rankings of 'Instructions with Landmarks' directions - Gender differences

Age - The analysis did not reveal any significant differences according to age. However, there were trends for subjects in the 55 plus age group to prefer sketches including road layout *more* and instructions with road and street signs *less* than those in the younger age groups, p=0.12 and 0.09 respectively. With respect to this second result, the extent of differences is reflected in the following histogram (Figure 4.6).

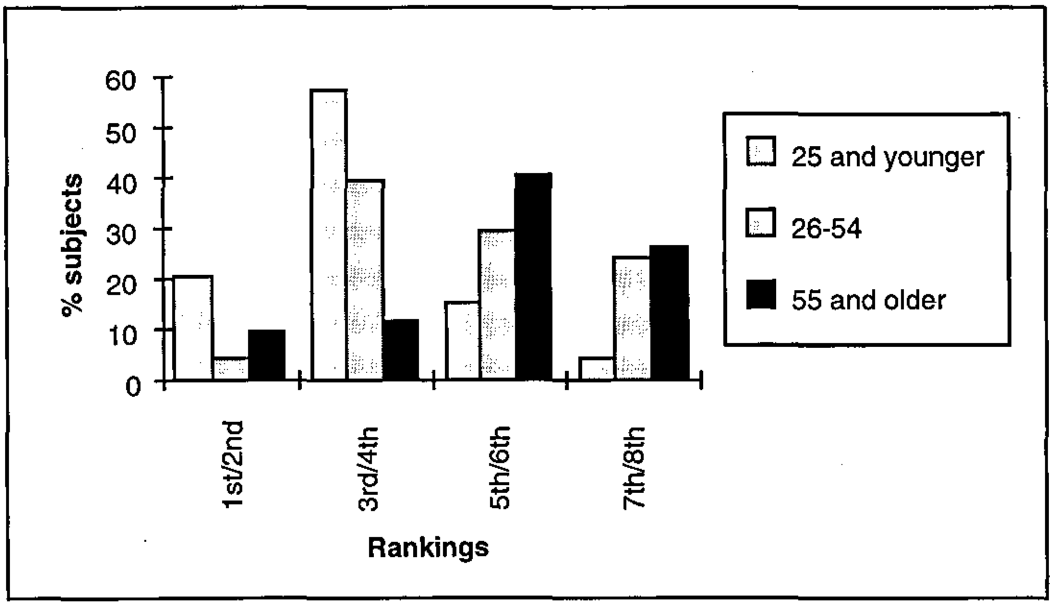


Figure 4.6 - Rankings of 'Instructions with Road/street signs' directions - Age differences

4.4.5 *Reasons for preference*

The following two tables summarise the results for the open-ended question regarding drivers' reasons for preferences, showing the numbers of subjects who made particular comments with respect to each of the information types and formats. A full list of the comments made is given in Appendix 4B.

	Positive comments	N	Negative comments	N
Landmarks	Good visibility - general	15	Some landmarks not named	3
	Known by others (e.g. pedestrians)	5	Too many landmarks, too close	2
			Exact location not known	2
	Distinctive/prominent	14	Landmarks are too small	6
	Next/close to turnings	2	Differing views of 'good' landmark	2
	Easy to remember	6	Dislike of mentioned landmarks...	
	Suitability in urban situations	3	- factory	3
	Provide reassurance/ confirmation	7	- park	6
			- church	1
	Suitability of mentioned landmarks...		- post-box	2
	- pub	16		
	- factory	7		
	- park	6		
Road/ street signs	Good visibility - general	5	Poor visibility - general	16
	Known by others (e.g. pedestrians)	1	Can be obscured by bushes/parked cars/other traffic	5
	Easily identifiable	3	May not be present/missing	2
	Likely to be present	1	Causes you to strain head/neck	1
	Easy to remember	1	Exact location not known	3
	Better for error correction	1	Have to slow down when searching	2
	Suitability in urban situations	4		
	Provide reassurance/ confirmation	5	Difficult to see at night	1
			Dislike of mentioned information	
	Suitability of mentioned info....		- A67	1
	- A67	3		
	- Queens Ave	1		
Distances	Suitability in urban situations	1	Reliability of the distance values	5
	Know if gone too far	4	Difficulty in judging distances...	
			- general	34
			- particularly for longer values	3
			Dislike of distances given in metres	2
			Dislike of approximate values (e.g. "about")	4
			Need to use car odometer	4
			Would not feel confident	3
Road layout	Allows counting strategy	12	Dislike/difficulty in counting turnings	10
	Ease of memorising turns	2	Reliability in number of turnings given	6
			Difficulty in establishing what constitutes a turn	6
			Need to remember how many turns have been passed	5
			Would not feel confident	1

Table 4.4 - Reasons for preference - information types

	Positive comments	N	Negative comments	N
Text instructions	Ease of memorising directions...	15	Does not give route overview	2
	Ease of maintaining current position (within directions)	3	Difficulty in reading whilst driving	8
			Have to memorise information	2
Sketched maps	Ease of memorising information	3	Difficulty in reading maps...	
	Ability to quickly reference...		- in general	4
	- in general	12	- whilst driving	2
	- whilst on move	4	Reliability of sketched maps...	
	Provides distance via scale	4	- in general	3
	Provides overview	5	- distances/scale	3
			Difficulty in memorising directions	2
			Difficulty in maintaining orientation	4

Table 4.5 - Reasons for preference - information formats

4.5 Discussion

4.5.1 Perceived usefulness of navigation information

The results in Table 4.1 reflect the effect of the environment on the value that drivers attach to different types of navigation information. For instance, it is evident that when travelling on dual carriageways/motorways (and to a lesser extent, rural roads), information on formal road signs is considered most important for wayfinding (e.g. junction numbers, road numbers, place names). The situation is markedly different on urban roads, since here it is road/street names, landmarks and road/junction layout that are considered to be most useful.

Such findings are in complete agreement with those of Burns (1997a), and partly reflect differences in the availability of information across driving environments. For example, in rural driving situations there are generally less landmarks present to help drivers, compared to urban driving situations. However, this reason cannot fully explain the observed effect, since, for instance, road signs are present in all three environments, and are designed specifically to aid drivers in finding their way.

It is likely that the primary basis for this result is related to differences in the complexities of the environments, affecting the ease or difficulty of navigational decision making. In out of town driving situations, there is generally relatively little uncertainty in navigating, as there are few possible decisions that can be made. Therefore, formal navigating means (i.e. road signs) will suffice. However, in more complex environments (e.g. cities), it is evident that drivers perceive the need for increased use of informal, context-based cues to enable successful navigation. Some problems with the use of road/street signs were generated by question C, and are given in section 4.5.4 below.

Taken as a whole, these results imply that there should be some adaptation in the presentation of information by a route guidance system to cater for changes in the driving environment. Information contained within road signs would appear suitable (or at least preferred) for fast road/rural driving, but in urban areas additional and/or different information is required (i.e. street names, landmarks, road/junction layout). A similar argument has been put forward by Schraggen (1991), based on the preferences of Dutch drivers for a route guidance system that employed road sign directions, and by Burns (1997a) based on his survey of UK drivers.

Compass directions were consistently rated as being of little use for wayfinding. Such a world-referenced scheme can be difficult to apply to turn-by-turn decision making (Mashimo, Daimon & Kawashimo, 1993; Wickens, 1992), essentially an ego-centred activity. Distance values (both long and short) were generally rated as less useful than the majority of the other information types, although short distances (e.g. 300 metres) were perceived to be of some use when travelling in urban areas.

These two results question the judgement of route guidance system designers who have assumed that drivers perceive a need for compass directions and exact distances. Absolute distances, and to a lesser extent, compass headings, are present in many HMIs for current route guidance systems (see the descriptions of systems in Table 9.3 and Appendix 9B). Indeed, many systems use distance values as primary information, such that a judgement of distance is required in order to locate an oncoming manoeuvre. The results of this survey suggest that drivers would find this prioritisation less acceptable than one in which distance values were secondary or confirmatory.

The requirement for the use of road sign information raises several issues concerning how such information is to be presented to drivers. Presently, many route guidance systems provide node-by-node (i.e. junction by junction) guidance. However, if one considers how information within road signs can be used in conventional directions, e.g. "follow signs to Leicester", it is clear that a node-by-node presentation could involve many redundant instructions, leading to the potential for driver irritation. Conversely, the presentation of single instructions for multiple junctions may reduce driver confidence in the workings of the system. Road trials are needed to resolve such issues.

A further issue concerns the choice of modality used for road sign information. The presentation of information such as road numbers within the auditory modality may create unacceptable demands on a driver's memory, especially when road numbers are long. It will also be important that road numbers are spoken in a way that is consistent with driver expectations. As an example, it is considered to be more appropriate to pronounce the road number, A6030, as 'A six '0' three '0'', rather than, 'A six thousand and thirty'. Simple laboratory trials could identify more specific requirements for issues such as this.

4.5.2 Perceived effectiveness of different landmarks

The five landmarks considered to be most effective for navigation were superstores, public houses (pubs), railway stations, street name signs and traffic lights. One could argue, therefore, that a route guidance system should employ such landmark types to assist drivers in navigation. However, closer inspection of the results in Table 4.2 suggests that these results should be interpreted with some caution.

In order to understand the result further, each of the 29 landmarks were placed within one of four basic landmark categories. Mean values were then calculated based on all landmarks included within a given category (i.e. means of means), as follows:

- Buildings/places with specific functions, e.g. railway stations (N=14, Mean = 3.4)

- Part of road/transport infrastructure, e.g. bend in road (N=8, Mean = 4.3)
- Objects external to road, e.g. post-box (N=5, Mean = 5.0)
- Part of the natural environment, e.g. wood/forest (N=2, Mean = 4.4)

As can be seen, landmarks with a particular function were generally rated more favourably than those in the other categories. Indeed, observation of Table 4.2 reveals that only two function-oriented landmarks were rated in the bottom 10 landmarks.

Background literature (see Chapter 6 for more details) postulates that a landmark with a function that is salient to an individual will become prominent within that individual's cognitive map. An example is the local swimming baths for someone who is just learning to swim. With respect to this survey, it is likely that many subjects were conceptualising a particular occurrence of a known landmark when making their ratings. In these instances, a natural bias towards selection based on function, rather than appearance may have arisen. In other words, one cannot be sure to what extent subjects were rating landmarks as effective based on their function, rather than their visual characteristics as an object within the environment. The methods used in Chapters 5 and 8 will aim to produce a more reliable list of 'good' landmarks.

4.5.3 Preferences for different styles of directions

With respect to drivers' preferences for different styles of directions, sketches that included landmarks were ranked most favourably, with 56.5% of subjects rating these as either their first or second choice. Sketches with road/street signs, followed by instructions with road/street signs, and instructions with landmarks were also rated favourably. Given the fact that this was an urban driving situation, the results generally confirm those found for question A, that is, that context-based cues, such as landmarks and street names are considered to be extremely important for navigating in towns and cities.

Interaction between information type and format provided some interesting results of relevance to the design of route guidance system HMIs. Analysis revealed that:-

- Landmarks were preferred more when in sketches (56.5%) than when in instructions (25%)
- Distances were preferred more when in sketches (23.5%) than when in instructions (7.5%)
- Road layout was preferred more when in instructions (18.5%) than when in sketches (4.5%)

These figures refer to the percentage of subjects who ranked the options as either their first or second choice.

It is felt that the first two results partly reflect the general preference that subjects had for sketched maps over instructions. Analysis of subjects' comments (see Table 4.5) revealed that many drivers felt that sketches could be more easily referenced on the move, provided there was some indication of distance via the scale, and had the advantage of providing an overview of the route (also reported by HUSAT, 1989). The inclusion of a greater proportion of male subjects in the sample would also appear to be a factor, since other sections of the questionnaire revealed that males had a general preference for spatial format information (e.g. maps), whereas females preferred verbal information (e.g. written notes). This gender result will be discussed in more detail in section 4.5.5.

It is believed that the above results also reflect the suitability of particular information types for presentation within a specific format. Landmarks for use in navigation contain spatial elements (e.g. where they are located in relation to a turning), which are best conveyed via a diagrammatic representation. Furthermore, distance, as a measure of the spatial separation between two points, will also be best represented in the form of a diagram.

The fact that road layout information was preferred more when provided as part of instructions probably reflects the fact that the instructions with road layout provided the number of turnings (e.g. "3rd left"). With regard to the sketch, additional processing would be required to count the turnings on the map, as well as those within the environment.

However, two other reasons may have led to this result. The sketched map with road layout, despite having more information regarding turnings along the route, looked sparse in relation to the others. Indeed, many of the comments directed at this style of directions concerned the perceived lack of information they contained (e.g. "is much too vague").

Furthermore, the fact that subjects were not informed that the road layout sketch actually showed all turnings may have reduced their confidence in its reliability. In defence of this decision, it was felt that the inclusion of any additional points (within the actual question) relevant to a specific style of directions had the potential to lead subjects in their rankings.

4.5.4 Reasons for preferences

Asking drivers to explain their rankings of the different styles of directions provided some useful data regarding drivers' opinions on the relative merits of different types of navigation information. With respect to landmarks, many positive comments referred to particular characteristics of these objects within the environment, e.g. their high visibility, distinctiveness, and location close to turnings. Other subjects noted that many people are aware of landmarks, so that they can be used if asking a passer-by. A further positive aspect of landmarks related to driver confidence, and concerned the ability of such information to reassure drivers that they were making correct decisions and hence were following the right route, e.g. "I prefer to know I'm on course because I've just passed a pub".

Although there were a smaller number of negative comments regarding landmarks, many also concerned physical attributes of this information. For instance, the difficulty in identifying the correct landmark when it is not named (e.g. "how do I know which church this is?"), establishing where the landmark is likely to be positioned (e.g. "Which side of the road is the park?"), or when there were likely to be others of the same type close by (e.g. "traffic lights are misleading, since you can have too many in the vicinity"). Other subjects felt that some of the landmarks mentioned were too small, and noted that people may vary in their opinions as to the characteristics of a good landmark along a route, thus leading to potential uncertainty.

Several subjects felt that road/street signs had positive physical characteristics, e.g. high visibility and ease of identification. The use of this information for confirmation purposes was also apparent from subjects' comments. However, more subjects made negative comments regarding road/street signs. These almost wholly concerned visibility aspects (e.g. the likelihood of signs being obscured by bushes or parked vehicles), the fact that signs are often not present at all, and the lateral, unpredictable positioning of such objects, requiring drivers to scan both sides of the road. These problems cited by subjects indicate one reason why informal methods, such as the use of landmarks, are often used in traditional navigation. Furthermore, they suggest that, until there is greater reliability of road/street signs (in terms of location, presence and visibility) within the environment, such information should only be utilised within route guidance systems for confirmation purposes (i.e. used redundantly).

Few specific positive comments were made with respect to the use of distance values in navigational directions. There were some indications made by subjects that distances provided indirect feedback with respect to missing a turning (e.g. "accurate distances help you realise that you've gone too far"). Generally though, subjects appeared unable to indicate why they preferred such information, and instead gave general comments, e.g. "I like to know about distances".

In contrast, numerous negative comments of a specific nature were made, for example, the unreliability of the direction giver's distance values, an aversion to approximate distances (e.g. "follow the road for "a while" is very, very vague"), and a lacking in general confidence when using such information. Most apparent was the finding that many people did not feel confident in judging values such as 300 metres or 3/4 mile for the purposes of locating a turning within urban areas (e.g. "It would be easy to misjudge the distances"). Indeed, some subjects felt that they would have to use the car's odometer to carry out this task, and pointed out that this would mean glancing away from the road.

It is important to remember that an urban driving situation was being considered, where the location of the correct turning was critical. In other environments (e.g. motorways/dual carriageways), distance values might be of use for providing a general indication of how far remains to travel, i.e. as part of advanced warning (commonly referred to as pre-information). As discussed in Chapter 2 (section 2.3.6), Burnett (1992) conducted a study which found acceptability benefits for a route guidance system that employed pre-information. Distance-to-turn values were part of the HMI for this simulated system.

With respect to the presentation of road layout information, many subjects commented that they liked to be able to count off turnings. However, other subjects expressed concern over the need to adopt such a strategy and noted that it could be difficult, given that:

(a) The number of turnings provided by the direction giver can be inaccurate.

(b) Turnings are open to interpretation, as commented by one subject, "I could count someone's drive as a turn .... I have done this!".

(c) A mental note of the number of turnings passed must be made.

Given the provision of precise information by a route guidance system, point (a) would become irrelevant. However, point (b) suggests that there will be some difficulties for drivers in using a route guidance system which uses a counting strategy as a primary means of conveying which turning to make. Extensive experience with a system may lessen such problems. Furthermore, additional information, such as road layout, landmarks or distance, may reduce the potential for uncertainty. An example concerns the voice message, "take 3rd turning left", which may be supplemented by the words, "... at crossroads", ".... at traffic lights", or ".... in 300 metres".

The load placed on a driver's memory by counting roads, as highlighted by point (c), raises the question as to how many 'turnings' can be given within navigational instructions. Further research should explore the variation in these demands as a function of the number of turnings given in an instruction. Furthermore, there is a need to establish the extent to which messages should be updated as turns are passed (e.g. "take 3rd left"... "take 2nd left"), balanced against the increased demands, pacing and poor driver acceptance that may be associated with multiple instructions.

A requirement which arose from many of the drivers' comments was the need for reassurance and/or confirmation in navigational decision making. It was also evident that some information, notably landmarks and road/street signs, were considered more important for confirmation purposes than distance values and road layout (counting turnings). It is felt that the greater potential of this information to minimise navigational uncertainty, and hence maximise driver confidence, led to this result.

4.5.5 *Individual differences*

With respect to individual differences, this survey served as an exploratory study highlighting some basic individual differences that have potential implications for the design of optimum HMIs for route guidance systems. Further research is needed to compare the behaviour and performance of different driver groups when using interfaces which contain various information elements.

Gender

The most apparent difference between male and female responses was the perceived benefits of landmarks for navigation purposes. As shown by Figures 4.1 and 4.3, females considered landmarks along the route to be of more use, and a number of different landmarks to be more effective, than did males. These results are in agreement with those of Ward, Newcombe and Overton (1986) - see Chapter 2. Also, the findings of Burns (1997a) provide some support for the results, since in his survey 11% more females than males expressed a wish for landmarks within 'ideal' directions given by a passenger.

Such gender differences improve one's confidence in the view expressed in Chapter 2 that the presentation of landmarks by a route guidance system would lead to greater system acceptability for females than for males. The underlying reason/s behind the result, however, are more difficult to establish. It was postulated in the literature review that drivers who perceive their abilities to be poorer may have a greater need for reassurance when navigating and may gain this from strong visual cues, such as landmarks. A finding of this survey (which was consistent with previous studies in the USA - Streff & Wallace, 1993; King, 1986) was that females perceived their navigational abilities to be poorer than did males. Therefore, there would seem to be good reason to believe that females require greater reassuring information, as a result of their perception of poorer navigational ability.

A further factor which may explain the preference of females for landmarks concerns the format in which information is provided. An important gender finding was that an interaction occurred between information type and format, since in question C females only preferred landmarks more than males when they were included within verbal instructions. There was no difference between the rankings of males and females for the sketch that included landmarks. This result suggests that it is partly the perceived suitability of landmarks for presentation within verbal instructions that is the primary reason why they are preferred by females. It is felt that such information can define nodes more clearly, than, for example, distance values.

In contrast to the above, there was a trend for males to consider compass directions to be more useful than did females. Furthermore, it was found that males had a greater preference for sketches with distances than did females. These two results are generally consistent with the findings of Ward et al. (1986), since in Ward's study males made greater use of cardinal directions and distances when providing navigational directions. The second result suggests an interaction between information type and format similar to that for females, that is, males prefer distance only when included as part of a sketch. In this case, it is felt that the root causes of the effect were (a) the suitability of distance information for spatial presentation, and (b) male drivers' general preference for the spatial format (as discussed below).

The results of question C (see section 4.4.4) suggest that females have a general preference for instructions (i.e. procedural information), whereas males have a greater preference for spatial format information (i.e. sketches). This was backed up by other sections of the questionnaire, since females generally preferred written notes, rather than paper maps, as a form of navigating. In addition, research within the general psychology literature confirms such findings with respect to female use of verbal over spatial wayfinding strategies. Lawton (1994) compared the navigational strategies of 288 female and 138 male students, and found that women were more likely to report a route strategy (i.e. attending to instructions on how to get from A to B), and men were more likely to report an orientation strategy (i.e. maintaining a sense of location in relation to external points).

The implications of this result are that a route guidance system employing greater use of procedural instructions (e.g. a turn-by-turn system) will be associated with greater acceptability for females than for males. The converse result may be expected for map-based systems (i.e. greater preference for males). The extent to which objective, performance-related benefits would also occur needs to be established via on-road trials.

Age

In general terms, this survey revealed that the older a male* driver was, the more useful he rated a number of different types of route information. Furthermore, older drivers generally rated many of the specific landmarks as more effective for the purposes of navigation. It is possible that this result was linked to navigating experience and the development of a global schemata for navigating, i.e. general strategies for wayfinding. In other words, drivers with a more extensive global schemata might realise the benefit of a wider range of information for the purposes of navigation than might those with few years of driving and navigating experience.

Although there was a general trend for older subjects to rate a greater range of information as more useful for navigation, it was evident that a stronger effect existed for certain information types over others. Specifically, compass directions within non-urban driving situations were considered by older drivers to be more useful. This result is consistent with Lawton's (1994) conclusions that older people are more likely to adopt an orientation-based wayfinding strategy, since world-referenced information, such as compass directions would undoubtedly aid in maintaining a sense of location.

Albeit not statistically significant, there were trends in the data for older subjects (i.e. those over 55) to prefer sketches with road layout more and instructions with street names less than did the younger groups. Although speculatory, it is possible that this result was due to the verbal content of the two direction styles, and the difficulty that older drivers may experience in reading such information (either within the environment or in print). For instance, the sketch with road layout did not contain any textual information, and so any problems that older drivers may experience with visual acuity would not be a factor - this may have caused older drivers to rank this style of direction more highly. With respect to instructions with street names, it is possible that the combined need to read textual instructions, and search for street names within the environment (both requiring high visual acuity), would have caused older drivers to rank this style less favourably. Indeed,

* As noted in section 4.4.3, age comparisons could only be made for male drivers.

the majority of negative comments concerning instructions and/or street names originated from the older subjects.

4.6 Conclusions

- It is evident that drivers' preferences for navigation information vary as a function of the environment. For instance, within faster roads, such as dual carriageways and motorways, formalised information within road signs (e.g. place names, road numbers and junction numbers) are considered most suitable for navigation. In slower urban driving, the situation is markedly different, since here drivers perceive a much greater need for informal, context-based information, such as landmarks, road layout and street names. Such results would suggest that route guidance systems should have HMIs that are adaptable to the current driving environment.

- The results found in this survey indicate that there is little perceived need for particular types of navigation information, notably compass directions. Distance values are rated to be of some use in urban areas, but it is argued that they should not be included as primary information within a route guidance system.

- Other information, such as landmarks and information within road signs (e.g. place names, road numbers) should be included within map databases, as they are rated as being extremely useful for navigation purposes. However, the reliability and quality of such information are critical issues, and means of ensuring these attributes are achieved and maintained should be sought.

- If information within road signs is to be presented by a route guidance system, then there are some interesting questions to resolve regarding how often road signs are referred to, and whether an auditory and/or visual presentation is more suitable.

- A concern was raised with respect to the validity in the list of landmarks rated by subjects to be effective for navigation. Many of the highest scoring landmarks had specific functions, and it is possible that subjects were considering known landmarks when making a judgement, rather than generic visual attributes.

- Sketches that included landmarks were considered to be the most popular style of directions in an urban area with 56.5% of subjects rating this either their first or second choice. This result demonstrates once again the perceived benefits that landmarks have in urban areas, and also partly reflects the general preferences that the sample had for sketches over verbal instructions.

- The study provided some early indications as to the factors that dictate good and bad information for navigation purposes. For instance, relevant characteristics of landmarks included visibility, distinctiveness, closeness to turnings, the inclusion of a label (where appropriate), and the degree to which landmarks of the same kind were likely to be close to one another.

- The most significant gender result concerned the finding that females perceived landmarks to be more useful and effective for navigation than did males. It was also found that females only preferred such information when contained within textual instructions, highlighting (a) the suitability of presenting such information within procedural directions, and (b) the general preference that females have for verbal format information. In contrast, there was some evidence that males had a greater preference for spatial format information (e.g. sketches and maps), and information more applicable to a spatial presentation, that is, compass directions and distances.

- Older drivers preferred a wider range of information than did younger drivers. Such a result suggests that increased navigational experience might lead to a realisation of the benefits of a variety of information types. In addition, there was some evidence that the reductions in visual acuity that are associated with age affect drivers' choices of styles of direction (e.g. preferences for maps with no textual information).

Chapter 5: Direction giving study - The choice of information from the 'real world'

5.1 Introduction

The importance of identifying suitable information for presentation by a route guidance system was established from the literature review in Chapter 2. The questionnaire study (Chapter 4) examined this issue by using drivers' general knowledge as a source of 'good' information.

The study reported in this chapter addresses the issue of information content from a novel perspective, by utilising the road and surrounding environment (i.e. the real world) as an 'ideal' information source. It is argued that the information which a driver actually sees on a journey and identifies as relevant for navigational decision making is the best basis for the content of information for a route guidance system.

The information that drivers extract for navigational purposes from the real world environment is contrasted with that taken from the limited information source of conventional paper maps. This comparison would seem to be an important one to make, since existing maps are currently the primary information source for the navigable databases upon which route guidance systems rely. A degree of groundwork is undertaken by map database companies, but the majority of inputted data is necessarily that which can efficiently be obtained (Van Duren & Lydon, 1997; Roser & Noonan, 1996).

The literature review highlighted the significance of developing a categorisation scheme for information elements that would be of practical use to a route guidance system designer, that is, establishing a framework in which to place different navigation information. Importantly, the study reported in this chapter also provides the data upon which such a scheme is proposed.

5.2 Aims

The primary aim of this experiment was to establish the information that drivers feel is needed to navigate successfully in an unknown area, based on either:

a) their own observation of the actual route - representing the real world environment

b) the use of a set of maps to extract information - representing the principal data source for current route guidance systems

In addition, the study aimed to develop a means of categorising information elements of potential use in the driver's navigation task, and therefore, of consequence to a route guidance system designer.

5.3 Experimental rationale

5.3.1 Choice of 'real world' environment

A method was required to enable subjects to extract information from the real world environment. The prospect of subjects viewing a route in real-time as a driver or passenger was discounted, primarily because of two major problems: firstly, the difficulties a subject would have attempting to note down or verbalise information retrospectively based on signposts, landmarks etc. that they had just passed whilst on a route; and secondly, the time pressures associated with attempting to note down or verbalise information in real time.

The most acceptable method of providing the information available from the actual environment was therefore considered to be to present subjects with a video image displayed on a television. A video playback machine would allow subjects to wind the image forwards and backwards to note down any information they considered necessary. The limitations of this method are discussed in section 5.6.4.

5.3.2 *Choice of experimental design*

An important issue was identified regarding the choice of experimental design - should the design be factorial (i.e. between subjects), in which each subject would experience only one route with one condition, or should it be a repeated design (i.e. within subjects) in which each subject would undertake both conditions on two separate routes?

In a repeated design it would be necessary to match the two routes, and it was felt to be impossible to achieve matching to a suitable level. The nature of this study was such that the information elements extracted by subjects would be affected considerably by the characteristics of the routes, and, therefore, a factorial design was considered appropriate, that is, each subject should undertake one condition, either video, or map both using the same route.

5.4 Method

5.4.1 *Experimental Design*

As discussed in the previous section, it was decided that the design of the experiment should be factorial. Therefore, subjects matched by age and gender, undertook one of the following:-

- Notes based on using *video* (n=15)
- Notes based on using *maps* (n=15)

5.4.2 *Subjects*

30 subjects (18 male, 12 female) were used in this experiment, mean age 34.7 (SD=10.01, range 23 to 59). The subjects were selected on the criteria that they could drive and were unfamiliar with the area in which the experimental route passed. Subjects were evenly allocated to the video or map conditions, whilst ensuring that the gender and age distributions were similar.

5.4.3 *Routes*

The choice of experimental route was of particular importance, because this would directly influence the types and amount of information available. The route was selected so that it included a variety of different road and junction types within residential and inner-city urban driving environments. Navigational decision making is typically complex in such circumstances, in comparison with motorway and rural driving situations.

The total distance of the route was approximately five miles, involved 32 distinct decision points (i.e. junctions where navigational uncertainty would be expected), and took approximately 30 minutes to drive. Table 5.1 shows the number of different types of junction that the route included. A map showing the route is given as Appendix 5A.

Junction type	**Number**
T-junction	7
Turn off road	13
Cross-roads	5
Roundabout	2
Lane change	5
TOTAL	32

Table 5.1 - Route details

5.4.4 *Materials*

The route was filmed in an experimental car in colour using a Toshiba micro 'lipstick' camera mounted in front of the rear view mirror and forward facing. The focal length of the lens was 7.5mm representing a viewing angle of 45 degrees. A Panasonic SVHS video recorder was then used to play back the route to subjects.

Subjects in the map condition were provided with the following two colour 'A-Z' street plan maps - for both maps, the route was marked using a highlighter pen:

- In the first, the relevant pages of the map had been cut out and stuck together to provide a whole view of the route to take. The scale of this map was 4 inches to 1 mile.

- The second map provided a larger scale for the city centre section of the route, in which one-way streets were marked. The scale of this map was 7.5 inches to 1 mile.

5.4.5 Procedure

The subjects were instructed to note down the information they felt they needed if they were to drive the route successfully. In addition, it was stressed that they could write notes, draw sketches or use a combination of the two, as they felt necessary. The subjects were led to believe that they would have to drive the route at a later date whilst using the information contained within their notes. It was felt that this would ensure subjects took their role seriously. However, it was stressed that they might not actually have to read the notes themselves whilst driving, and that information might be read out to them.

The time taken by subjects to make notes from the video was generally longer when using the video (mean 30 minutes; range 16-50 minutes), as compared with the maps (mean 20 minutes; range 10-38 minutes).

5.5 Results

5.5.1 Categorisation scheme

In order to analyse the data, it was necessary to make use of a scheme for grouping types of information. As argued in the literature review, the categorisation schemes employed in previous studies (e.g. Alm, 1990; Akamatsu et al., 1994; Schraggen, 1990) can be criticised for being at too high a level, and hence cannot be readily understood and applied by designers of route guidance systems. Therefore, it was decided that some more detailed, specific categories should be developed. Observation of the literature, plus a card sort exercise (Gammack & Young, 1984), formed the basis for the final recommended categorisation scheme.

Background literature

Three basic information types emerged from the literature review (Chapter 2), each of potential use in the route following task:

- *Direction information* - indications of which direction the driver should take (Färber, 1993). Alm (1990), based on Gärling and Golledge (1989), broke this down into use of ego-centred, local, and world reference schemes.

- *Distance information* - a measure of the spatial separation between two locations (Downs & Stea, 1977). These authors also proposed three types of distance information: absolute, relative and cost-based (p.47).

- *Environment information* - aspects of the drivers' surroundings. The work of Lynch (1960) has been used in the past for decomposing environment information, that is, as paths, nodes, landmarks, districts and edges (Alm, 1990; Obata et al., 1993). A need for more practical categories was identified in the literature review, and a card sort procedure was employed as a means of achieving this aim.

Card sort

The ultimate aim of the card sort procedure was to establish a consensus of opinion as to what constituted reasonable categories for environment information. Eight human factors specialists carried out the card sorting process. A total of 171 separate elements of environment information had been reported by the 30 subjects (e.g. traffic lights, Warwick Way, second turn, bridge), and these were written on the same number of cards. The raters were instructed to sort the cards into what they considered to be reasonable categories and then to give labels to those categories. In addition, the raters were told that the number of categories they chose could be as large or as small as they desired, and they could include sub-categories. Where appropriate, the context in which information was noted by the subjects was also given on the cards. For example, "{turn right} immediately after {the church}". In this case, the subjects were informed not to categorise the information within the brackets, but to use it to understand the relevance of the phrase outside the brackets.

In order to generate the general consensus categories, all of the raters' categories and the types of information given within each (e.g. "types of junction" - T-junction, Roundabout, etc.) were listed. These data were then observed by the author to determine where there was a majority agreement between the categories given by the raters. No formal statistics were involved during this process.

It was found that for certain types of information there was more or less an agreement as regards categories and the types of information to be contained within them, for example, street signs (Aylmer avenue, Hilders road), landmarks (bridge, traffic lights, post-box, etc.), junction type (roundabout, crossroads, T-junction), etc. However, with regard to other pieces of information, e.g. "middle lane", "follow one-way system", "the hill", there were some differences of opinion between the raters, such that information was often put into an "other category". It was decided that the author should make judgements on suitable categories for such information.

Despite the problems encountered with respect to certain pieces of information, there appeared to be an interesting link between many of the categories selected by the raters and three of the physical elements found in the work by Lynch (1960), i.e. paths, nodes and landmarks. This was due to the fact that many of the raters' categories could be assigned to one of the above elements as being information *about* that element.

Information present within road/street signs is considered as a separate 'environment' category, rather than part of Lynch's breakdown. This result reflects the specific use of this information for navigating purposes - in Lynch's more general view one could imagine road sign information to be split across a number of the different categories, e.g. path (road/street name, road number), node (junction name), landmarks (point of interest name), district (place names).

Proposed categorisation scheme

Table 5.2 shows all of the information types within the proposed categorisation scheme, together with descriptions and some examples. The words underlined in the examples illustrate the key aspects of the information. In section 5.6.3 the utility of the scheme and problems encountered in classifying information are discussed.

Category	Elements	Description	Examples
Direction	**Ego**	Direction is defined in relation to the imagined/ viewed position of the car driver	turn left, go straight on
	Local	Direction is defined in relation to an external reference point	turn towards the post-box, 2nd exit at roundabout
	Global	Direction is defined in relation to a system that can be applied all over the world	head northwards
Distance	**Absolute**	Precisely given distance values	300m, half a mile
	Relative	Distance given relative to some other marker	half way there
	Cost-based	Distance given in cost terms (time, effort etc.)	turn immediately, a long way
Environment - Path (road)	**Class**	Information about the class or type of road between junctions	A47, dual carriageway
	Geometry	Information about the geometrical layout of the road	bend in the road, dip in the road
	Lanes	Information regarding which lane to take	keep in right-hand lane
	Road-rules	Information about the rules of the road along the path	follow one-way system. no-entry st
	Prior turns	Information regarding turns along the path prior to an oncoming manoeuvre	2nd left, 3rd exit
Environment - Node (junction)	**Angle**	Indications of angle of junction	sharp turn, bear left
	Junction type	Information which indicates the form of the oncoming junction	T-junction, Xroads, roundabout
Environment - Landmarks	**Name**	Name of a particular class or type of landmark	traffic lights, petrol station, pub, shop
	Descriptors	Additional descriptive information that would help in identifying a landmark	the white house, big tree, low bridge, Shell petrol station
	Locators	Information that would help in locating a particular landmark	post-box on the corner, church on left
	References	A preposition that references a landmark to a manoeuvre	turn right just before church, left at lights
Environment - Road/street signs	**Place name**	References to a place name (on, or likely to be on a road sign)	Loughborough, Derby
	Point of interest name	References to a point of interest (on, or likely to be on a rd sign)	Warwick castle, City museum
	Road number	References to a road number (on, or likely to be on a rd sign)	A417, M1
	Road/street name	References to a road/st name (on, or likely to be on a rd sign)	Park Drive, Elms Grove
	Junction name	References to a junction name (on, or likely to be on a rd sign)	Northwood roundabout

Table 5.2 - Categorisation scheme for navigational information elements

5.5.2 Styles of directions

The following table reports the number of subjects who noted directions in a particular style. The table shows that the vast majority of subjects made written notes in this study, and that there was little difference between the map and video conditions with respect to the overall style of subjects' directions.

Style of directions	MAP	VIDEO
Purely verbally-based information (i.e. written notes)	10	12
Predominately written notes with some graphics for 'complex' manoeuvres	4	2
Predominately symbol-based information with some supporting text	1	1
Total	n=15	n=15

Table 5.3 - Styles of directions employed by subjects

5.5.3 Information types

Table 5.4 shows the mean, standard deviation and range for the number of references made by subjects to the different types of information (as developed in 5.5.1), based on the map or the video.

The following points outline those key results within the above table that reached significance, based on unpaired t tests:-

- Subjects in the video condition made more use of *ego-referenced directions* than did those in the map condition (Means: 36 vs 26; $t(28)=-6.40$; $p<0.0001$)
- Subjects in the map condition made more use of *absolute distances* than did those in the video condition (Means: 2 vs 0; $t(28)=2.30$; $p<0.05$)
- Subjects in the video condition made more use of *path (road) geometry* than did those in the map condition (Means: 4 vs 1; $t(28)=-3.63$; $p<0.005$)
- Subjects in the video condition made more use of *lane references* than did those in the map condition (Means: 4 vs 0; $t(28)=-6.35$; $p<0.001$)

	MAP (n=15)				VIDEO (n=15)			
Information type	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**
Direction - Ego	26	3.3	32	20	36	5.3	46	28
Direction - Local	2	1.4	5	0	3	0.8	4	1
Direction - Global	1	0.9	4	0	0	0.3	1	0
Distance - Absolute	2	2.5	7	0	0	0	0	0
Distance - Relative	1	1.3	5	0	0	0.4	1	0
Distance - Cost-based	2	1.8	5	0	2	1.3	5	0
Path - Class	5	2.7	10	0	4	2.4	7	0
Path - Geometry	1	1.0	3	0	4	3.1	10	0
Path - Lanes	0	0.4	1	0	4	2.4	9	0
Path - Road rules	1	0.9	3	0	1	0.9	3	0
Path - Prior turns	8	2.9	13	3	5	2.2	8	1
Node - Angle	3	3.8	10	0	3	5.6	23	0
Node - Junction type	11	3.8	17	5	15	5.6	31	7
Landmark - Name	4	3.5	13	1	20	7.5	33	9
Landmark - Descriptors	1	0.9	3	0	4	2.5	8	0
Landmark - Locators	1	1.4	4	0	4	2.2	8	1
Landmarks - Reference	2	2.9	8	0	8	3.8	16	1
Signs - Place name	0	0.4	1	0	2	1.6	5	0
Signs - Pt of interest name	1	1.4	5	0	2	1.4	5	0
Signs - Road number	3	2.0	6	0	1	1.7	5	0
Signs - Road/street name	22	6.6	30	5	11	3.9	18	5
Signs - Junction name	1	0.6	2	0	0	0.5	1	0
TOTAL	95	20.7	127	68	131	21.1	176	99

Table 5.4 - References to different information types

- Subjects in the map condition made more use of *prior turns* than did those in the video condition (Means: 8 vs 5; $t(28)=3.50$; $p<0.005$)
- Subjects in the video condition made more use of *junction types* than did those in the map condition (Means: 15 vs 11; $t(28)=-2.51$; $p<0.05$)
- Subjects in the video condition made more use of *landmark names* than did those in the map condition (Means: 20 vs 4; $t(28)=-7.83$; $p<0.0001$)
- Subjects in the video condition made more use of *place names* than did those in the map condition (Means: 2 vs 0; $t(28)=-4.00$; $p<0.005$)

- Subjects in the map condition made more use of *road/street names* than did those in the video condition (Means 22 vs 11; $t(28)=5.60$; $p<0.0001$)

- *In total*, subjects in the video condition made references to more information types than did those in the map condition (Means 131 vs 95; $t(28)=-4.70$; $p<0.0001$)

5.5.4 Landmark types

An analysis investigated in greater detail the specific types of landmarks referred to in the map and video conditions. The full details of this are given in Appendix 5B. In summary, the key results of this analysis were:

- Subjects in the video condition referred to a much greater range of landmarks (23 separate types) than did those in the map condition (10 separate types). Examples of the more atypical landmarks were railings, hedges, trees and walls.

- In the video condition, the most referred to landmark type was traffic lights with each subject making an average of 9 references throughout the route (SD=3.9; max 14; min 2)

- In the video condition, several references were also made to shops (mean 2; SD=1.7; max 6; min 0); bridges (mean 1; SD=0.7; max 2; min 0); and schools (mean 1; SD=0.8; max 3; min 0)

- In the map condition, the most referred to landmark type was bridges with each subject making an average of 0.5 references throughout the route (SD=1.0; max 3; min 0)

- Other landmarks commonly referred to in the map condition were schools (mean 0.4; SD=0.5; max 1; min 0), park/gardens (mean 0.3; SD=0.8; max 3; min 0), and churches (mean 0.3; SD=0.6; max 2; min 0).

5.5.5 Errors

An error was defined as having occurred when a subject noted an item of information that would obviously lead to severe difficulties if they were to attempt to drive the route using that information. The data were categorised into several error types, and the total number of errors made for each condition are shown in Table 5.5.

Type of error	MAP (n=15)	VIDEO (n=15)
Mixing up left/right	17	5
Miscounting number of side roads before turning	3	11
Missing out sections of the route	4	0
Mis-judging/reading distances	5	0
TOTALS	**29**	**16**

Table 5.5 - Errors made in using map/video

Unpaired t-tests revealed that the number of errors made by subjects using either the maps or the video were significantly different at the 5% level for all error types, including the total values. The table shows that a greater number of errors were made in the map condition, and these could be largely attributed to subjects mixing up left and right. In the video condition, however, a number of subjects miscounted the number of side turns required before a turning.

5.5.6 Combination strategies

An analysis was carried out to investigate how subjects combined the different information elements across the individual manoeuvres of the route. It was felt that this would reveal some interesting differences with respect to the use of generic (i.e. across the route) versus junction-specific combinations.

The ten most popular combinations for the map and video conditions are shown by Table 5.6. The figures in columns refer to the percentage of times that particular combinations of information elements were noted across all subjects and manoeuvres. The table also shows the total number of unique combinations of information elements for the two conditions.

	MAP (n=15)		VIDEO (n=15)	
Rank	**Combination**	**% times noted**	**Combination**	**% times noted**
1	DE/PP/SN (e.g. 2nd left into Park Drive)	24	DE/PP/SN (e.g. 2nd left into Park Drive)	8
2	DE/SN (e.g. turn right into Park Avenue)	21	DE/NT/SN (e.g. turn right at the T-junction into Westfield road)	8
3	DE/NT/SN (e.g. turn right at the T-junction into Westfield road)	18	DE/LN/LR (e.g. turn right at school)	7
4	DE/NT (e.g. turn right at X-roads)	8	DE/SN (e.g. turn right into Park Avenue)	7
5	DE/dA/SN (e.g. turn right into Aikman Ave in 300m)	6	DE/NT (e.g. turn right at X-roads)	6
6	DL/PP/NT/SN (e.g. 3rd exit at roundabout into Letchworth road)	4	DE/NT/LN/LR (e.g. turn right at X-roads by school)	5
7	DL/PP/NT (e.g. 2nd exit at roundabout)	3	DE/PL (e.g. move into the left hand lane)	4
8	DE (e.g. turn right)	3	DE/PP (e.g. 2nd right)	4
9	DE/PP (e.g. 2nd right)	2	DL/PP/NT (e.g. 2nd exit at roundabout)	3
10	DE/LN/LR/SN (e.g. turn right into Park Road at Church)	2	DE/PP/LN/LR (e.g. 2nd turning right at school)	3
	Total (given by top 10)	**90%**	**Total (given by top 10)**	**55%**
	Unique combinations = 17		**Unique combinations = 46**	

Table 5.6 - Popular combinations of information elements

Key

DE = Ego-referenced direction, e.g. turn <u>right</u>

DL = Local-referenced direction, e.g. <u>2nd exit</u>, drive <u>towards</u> school

dA = Distance - absolute, e.g. <u>300m., half a mile</u>

PP = Path, Prior turns, e.g. take <u>2nd</u> turning

PL = Path - lane information, e.g. take middle <u>lane</u>

NT = Node - type of junction, e.g. <u>T-junction</u>, <u>Crossroads</u>

LN = Landmark - name, e.g. <u>postbox</u>, <u>house</u>

LR = Landmark - reference information, e.g. <u>before</u> church, <u>at</u> flats

SN = Road signs - street name, e.g. <u>Park Drive</u>

Briefly, Table 5.6 shows that, within the map condition there was a significant emphasis on a relatively small number of generic combinations of information types. Indeed, almost 60% of all the map-derived directions could be attributed to one of three particular combinations. This was not apparent within the video condition, where a far greater variety of combination strategies were employed, that is, the combinations of information elements were more junction-specific in nature.

5.6 Discussion

5.6.1 'Ideal' Information types

The primary aim of the study was to establish which information a route guidance system should provide to drivers, based on the actual observation of the route as an 'ideal' information source (via a video). The most prevalent information extracted by subjects from the video was ego-centred directions, landmarks, junction type, road/street names and prior turns. However, it is clear from Table 5.4 that a wide range of different information (e.g. required lanes, road geometry, place names) available within the 'real world' was considered to be of use in the navigation task. In addition, a wide variety of landmarks were extracted from the video ranging from commonly used navigational cues (e.g. traffic lights, bridges) to less obvious cues (e.g. hedges, trees, walls).

The map condition was chosen to represent the equivalent information source for current route guidance systems. In contrast with the video, subjects extracted relatively few landmarks from the maps, and an increased emphasis was placed on road/street names, prior turns (i.e. counting turns) and absolute distances. In addition, the range of information referred to was more limited with the five most popular information types (ego-centred directions, road/street names, junction type, prior turns and path-class) accounting for over three quarters of all reported information. It is interesting to note that these information types relate well to the most predominant information present within current route guidance systems (see Table 9.3 in Chapter 9 and Appendix 9B).

Of particular importance was the finding that subjects in the video condition utilised a large number of different strategies for combining information (as shown by Table 5.6), whereas relatively few unique combinations were employed by those using the maps. Indeed, from the map four information types (ego-centred directions, prior turns, road/street names and junction type) covered the vast majority of combinations.

These differences between the two conditions primarily show that subjects in the video condition had access to a) a wider range of different information, and b) information upon which decisions regarding quality could be made. As a consequence, it is apparent that subjects extracted information from the 'real-world' to suit the particular circumstances (i.e. on a junction-by-junction basis), whereas from the maps information was utilised generally across the route, regardless of the situation (i.e. as generic combinations).

Taken as a whole, the above results suggest a need for the development of, as termed by the author, 'context-dependent' route guidance systems, capable of providing different information to suit particular navigational situations. In order to support such intelligent systems, navigable map databases would have to contain a wide range of information (particularly landmark types), and also information regarding the quality of such information. The study reported in Chapter 7 makes a first step towards developing criteria for selecting 'good' information, specifically landmarks.

The following sections discuss in detail the results of this study with regard to the different information types.

Direction

Table 5.4 clearly demonstrates that the egocentric reference scheme (e.g. left/right) was by far the most common method used to indicate the direction to drive. In comparison, there was relatively little use of the local and global reference schemes, a result which is generally consistent with the findings of Alm (1990). The local reference scheme was occasionally used in combination with ego-centred directions and a proximate landmark (e.g. turn left towards the school), confirming the view of Alm that such combinations of information may be applied by a route guidance system in particular situations (i.e. when an appropriate landmark is present).

The local reference scheme was also used to indicate change of direction at small roundabouts. An instruction such as " take 2nd exit" informs the navigator of prior turns, and also enables a local reference to be identified (in this case the exit, viewable prior to entering the roundabout). In contrast, for larger roundabouts, a desired exit may not be viewable from a distance, thus forcing the driver to rely on counting turnings so that the local reference is lost. Such a situation reflects the uniqueness of the roundabout problem, and the need for further research regarding the optimum means of presenting information for different sizes and complexities of roundabout.

With respect to differences between the video and map conditions, the former involved a much greater number of direction changes being stated using the egocentric scheme. More detailed observation of the data revealed that use of lane references (e.g. take right hand lane), and increased use of 'continue' references (e.g. straight ahead at crossroads) accounted for the difference. The second point suggests that subjects in the video condition actively sought information for the purposes of overall confidence, for example, to confirm they were going the right way. Road trials are needed to examine whether such information would be excessive for presentation within a route guidance system.

It was not expected that subjects in the video condition would make use of any globally oriented directions (e.g. head northwards), since the video provided no overall frame of reference. However, the global reference scheme was used by only two of the subjects referring to the maps, suggesting that subjects perceived little need for such information within manoeuvre-related instructions (confirming the results of Chapter 4). This does not mean that route guidance systems should not employ global references at all, since (as stated in previous chapters) there is evidence that such a scheme is considered to be valuable within a map for general orientation purposes (HUSAT, 1989).

Distance

Relatively few references were made to distance-related information in this study. This is not a surprising result given the difficulties in extracting distance information from the video, and the need to refer to a scale on the map. However, the result can still be seen as evidence that drivers do not perceive a great need for such information in navigational instructions, as discussed in Chapter 4.

From the video, no references were made to absolute (e.g. 300 metres) and relative distances (e.g. half way there). Although some references were made from the map, there were also several errors, such that drivers would have experienced difficulties in using their distance values. In both conditions, cost-based distances were used in particular circumstances, e.g. the word "immediately" when two turns were close to one another, or the phrase "a long time" when turns were widely separated, suggesting that such information is more natural and consistent with how drivers perceive distances (i.e. as near/far).

These results are of particular interest, since many of the current route guidance systems make considerable use of absolute and relative distance information, but make little reference to cost-based distances. The implication is that route guidance systems should not employ absolute and relative distances and instead use less exact cost-based information. This point will be discussed in more detail in Chapter 9, section 9.4.1.

Path (road)

A wide range of different path-related information was extracted from the video to aid in the navigation task. Several references were made to geometrical information about a path, and this included the layout in three dimensions, e.g. dips in the road, hills, bends in the road. Information regarding the class of the road was also noted, and in the video condition this information was provided via direct references (e.g. a main road), or indirectly via a reference to a road number (e.g. A47).

Of particular importance was the finding that subjects using the video noted a great deal of information about the lanes of the road. The results show quite clearly the perceived value of such information in inner-city situations (also found by Burns, 1997a), since in this study 13 of the 15 subjects using the video noted one or more pieces of lane information.

In the map condition, subjects made more references to prior turns, that is, they made greater use of a counting strategy for locating manoeuvres. The general lack of availability of other, preferred information such as landmarks most likely forced the use of such a method. Several of the current wave of route guidance systems also employ such a strategy (see Table 9.3 and Appendix 9B). However, as established in Chapter 4, there are reported difficulties in reliance on such information, since demands are placed on a driver's memory (i.e. how many turns are there left/have been passed by), and it may not be clear as to what constitutes a turn.

Node (junction)

It is evident from the results that information regarding junction type (e.g. T-junction, crossroads, roundabout) is considered a powerful navigational cue. This was the case in both map and video conditions, although from the video there was a tendency for more information of this type to be noted. These results probably reflect the strong expectations associated with junction type (e.g. drivers will have a well developed mental model of what a T-junction looks like), and indicate the suitability of this type of information for presentation by route guidance systems.

Nevertheless, a point must be made regarding the applicability of junction type information across different navigational situations. It was evident from detailed observation of the data in this study that, within the more complex inner-city driving manoeuvres, several junctions did not fit into neat categories. Within the video condition and in these situations, subjects made greater use of context-specific information, particularly proximate landmarks, information within road signs (e.g. place names) and recommended lanes.

Generally few references were made to junction angle information in both conditions, partly reflecting the fact that there were few manoeuvres with gross angles (sharps or bears). The large range in the number of references made at the subject-specific level (see Table 5.4), particularly in the video condition, are caused by the two subjects who predominately used symbols to represent manoeuvres. In the categorisation scheme, it was felt that such graphical representations provided exact junction angle information, whereas use of words such as "turn left" were not felt to provide any indication of junction angle. This raises a methodological problem in allowing subjects free access to the style of their choice (e.g. written text, drawings, combinations), an issue which will be discussed in more detail in section 5.6.4.

Landmarks

The most apparent of the differences between the map and video conditions concerned references to landmarks. It was anticipated that there would be more references to landmarks within the video condition, as the 'real world' environment contains considerably more examples of this type of information for drivers to extract. Nevertheless, this should not distract from the importance of the result, since it shows the perceived value that drivers attach to such information, and thus the basic need for their inclusion within route guidance systems.

Traffic lights were considered to be extremely important landmarks by those subjects using the video, since an average of 9 references were made to these. At the subject specific level it was found that all of the 15 subjects using the video noted at least two traffic lights, and further that three subjects noted 14, which was the maximum number of traffic lights observable. In addition, shops were considered to be important landmarks by those using the video, as were bridges and schools.

Table 5.4 shows that subjects referred to more than just the landmark name when using such information for the purposes of describing the route to take. Supplemental information was given to aid in the following:

- locating the landmark (e.g. postbox *on the corner*)
- identifying the landmark (e.g. *white* house)
- the subsequent relating of the landmark to a manoeuvre (turn right *before* the petrol station)

The requirement for such information highlights a factor relevant to the quality of different landmarks. It is argued that 'good' landmarks require the minimum of additional information to make them usable. As an example, the position and appearance of traffic lights is evident purely from the class name. Poorer landmarks (e.g. the iron railings on the left hand side) will be associated with increased demands within a route guidance system interface, since the driver will be required to process several different information elements.

Road/street signs

The most commonly referred to information present within the road/street signs category was road/street *name* (e.g. Park Drive). This was the case in both the map and video conditions. On average, there were half as many references to such information in the video as in the map, and it is felt that this occurred primarily because many road signs could either not be seen on the video, or were not available to be seen. That is, subjects were noting those street signs they considered to be visible. Furthermore, this difference might have occurred because less traditional landmarks were available on the map, and so the subjects compensated by noting more road/street names.

On this subject, it is worth noting the results of Schraggen (1990), since he found a link between high reliance on street signs and poor navigational performance. Such a finding suggests that subjects in the map condition of this study would have experienced difficulties in actually using their notes for finding their way. This point is shown most clearly when examining the combinations of information present in Table 5.6, specifically the second most popular combination (reported for 21% of situations), ego-centred directions together with road/street name (e.g. turn right into Park Drive). It is felt that such a combination of information elements would have led drivers to slow down as they passed each turning, since they would have had no indication as to the immediacy of the turning.

5.6.2 *Individual differences*

Although this study did not focus on individual differences per se, it is clear from observation of the standard deviations and ranges present in Table 5.4 that subjects varied considerably on the following dimensions:

- The amount of information elements referred to, the maximum being 176 elements and the minimum being 68. These differences suggest that there is substantial variability in drivers' perceived needs for supplemental or redundant information for supporting the navigation task.

- The reliance on particular information elements, with some subjects placing a greater emphasis on landmarks, others on road/street signs, others on junction type, etc.

Taken as a whole, these results strengthen the arguments made in Chapters 2 and 4 for the development of interfaces for route guidance systems capable of adaptation to individual needs. As discussed in Chapter 2, there has been little consideration of the individual differences present within research findings, and further research is required to establish the underlying reasons behind such variability.

5.6.3 Categorisation scheme

The categorisation scheme was developed through a consideration of the research literature and a card sort exercise. The categories formed were considerably more detailed than those used in any other study, and enabled differences between the map and video conditions to be clearly shown. The scheme has significance beyond this study, since:

- It provides a framework in which to compare the results of research studies in the future. As discussed in Chapter 2, a criticism of previous work has been that information, particularly landmarks, has been defined in different ways, thus making comparisons difficult.

- It provides a means of specifying the information content of any particular style of interface for a route guidance system. In the overview chapter of this thesis (Chapter 9), the information content of sample screens and voice messages for a range of current systems is explored.

Ultimately, it is felt that the scheme generated in this study could be used in conjunction with knowledge regarding the suitability of different information for aspects of the navigation task. As such, it could form the basis for the first stage of a tool to aid in the design process for route guidance systems. Chapter 9 of this thesis will draw together the findings within the various studies of the PhD, as well as those within the general research literature, in order to make a first pass at the suitability of the different information elements.

As a final point, one particular issue that arose in the formulation and use of the categorisation scheme concerned the role of implicit versus explicit references. The nature of any language means that a reference to a particular information element could be given implicitly. As an example, the direction, "3rd exit at roundabout" could be considered to suggest a right turn for roundabouts within the UK. In addition, the instruction, "turn left at the bottom of the road" implies a slope in the road. For this study, information was only included in a particular category if it was an explicit reference, the reasoning being that it would not be recommended for a route guidance system to contain information which is open to interpretation.

5.6.4 Methodology issues

Many of the points made above relating to this study and regarding the choice of information for a route guidance system are based on the assumptions that, a) the video acted as an 'ideal' information source, and b) the subjects extracted 'good' information types for use in the navigation task.

It is evident that both of these assumptions can be criticised. With respect to (a), the following points can be made:

1) The obtained resolution of the video images was such that several road signs could not be read clearly by the subjects. Green et al. (1993a) have also noted the difficulties in obtaining sufficient resolution for route guidance research when using video images. In order to compensate for this problem, the subjects were instructed to ask the experimenter for the names of any road signs that they could see and wanted to note, but could not read.

2) The video did not provide an overview of the route to subjects, and it is inevitable that subjects notes concentrated on a manoeuvre-by-manoeuvre description. Therefore, although this study found little evidence of a need for overall orientation information, this does not mean that such a need does not exist.

3) A number of errors were made by those using the video as a result of them miscounting the number of side roads before their turn off. This occurred because i) certain side roads were partly obscured by parked cars, signs etc. on the video, and ii) because many subjects wound the video on fast-forward until they reached the next turn and hence missed some of the earlier turns.

With respect to point (b), the central difficulty of 'direction-giving' studies such as this one is that there is a reliance on drivers' abilities to provide good directions. As commented in Chapter 2, it is evident that drivers differ in their ability to carry out this task (Streeter & Vitello, 1986), and it is likely that there will be considerable redundancy in the information provided.

Thus, it is apparent that the results of the current study will have greater implications for the acceptability, rather than effectiveness (e.g. navigation errors) and/or efficiency (e.g. workload) components of route guidance system usability. Road trials would seem to be the most appropriate means of testing performance-related attributes of a system HMI, and, in this respect Chapter 8 presents the results of a comparison made across two road-based studies.

Finally, in retrospect it is thought that it would have been better to force subjects to use either text only or graphics only and not to allow a free choice. Although the majority of subjects in this study made purely verbal notes (i.e. written instructions), the information within graphics skewed the data for particular 'spatially-oriented' information elements. As an example, it was considered that all graphics explicitly showed junction angle and junction type, whereas written notes such as "turn right" did not.

5.7 Conclusions

- The results of this study suggest that there needs to be a fundamental change in the philosophy adopted in the design of the HMI for route guidance systems. Many current systems utilise generic combinations of information such as road/street names, prior turns and absolute distances when presenting information to the driver en-route. However, when provided with a simulated 'real-world' environment, drivers extracted a wide range of different information for the purposes of supporting the navigation task. Furthermore, information was combined on a junction-by-junction basis (rather than across the route) to suit the prevailing circumstances. In other words, it was clear that drivers perceived a need for navigation information specific to their particular navigational situation. In short, these findings suggest that future route guidance systems should employ high levels of 'context-dependency' if they are to be consistent with drivers' preferences.

- The contrast with current system designs was most stark with respect to the use of landmarks and information within road signs. Subjects in this study expressed a strong need for a wide range of different landmarks (29 distinct types) and also information within road signs (e.g. place names, road numbers). Unfortunately, it is evident that such information varies considerably in quality from situation to situation (e.g. when there are several sets of traffic lights close to one another, when a road sign is hidden, etc.). Therefore, it is not recommended that all examples of such information should be included within databases, or indeed presented for all manoeuvres where they are known to exist. What is required is research that will encourage the future development of databases, so that a link exists between information elements and their intrinsic quality (e.g. presence, visibility, location). This issue will be explored in more detail in Chapter 7 of this thesis.

- The data generated in this study enabled the development of a detailed categorisation scheme for describing information elements of use in the driver's navigation task. As such, it provides a framework in which to compare the results of future research studies, thus fulfilling an important need evident from observation of the research literature. Perhaps more importantly, the scheme provide a means of specifying the information content of any particular style of HMI for a route guidance system, and may consequently form the basis for a design/evaluation tool. Chapter 9 of the thesis will develop the categorisation scheme further by consideration of the information present within current route guidance systems.

Chapter 6: Literature review - Landmarks and their role in spatial cognition

6.1 Introduction

A common result across the studies presented within Chapters 4 and 5 was that landmarks (e.g. traffic lights, petrol stations, churches) are perceived to offer significant support to drivers in the navigation task. Chapter 7 describes a study which focused on the key question: which landmarks should be presented by route guidance systems to support the driver's navigation task? Prior to this study, it was thought necessary to acquire background knowledge regarding landmarks, therefore, a brief review was conducted of the 'landmark' literature within non-human factors domains. The majority of relevant research was found within the environmental psychology and human geography fields, although the review also revealed interesting work conducted by sociologists, architects, and town and city planners.

The review was not exhaustive for two reasons. Firstly, the perspective of this PhD is a human factors one, and so an analysis of the literature in that domain should be central to the thesis. Secondly, as common objects in peoples' mental representations of their environment, landmarks have been researched and commented on by a considerable number of authors. It was felt that a review of all such references would not merit any advantage over a summary critique for the purposes of the thesis.

In conducting the examination of the background literature, review papers within recognised journal papers were sought in the first instance. References given by these papers were then pursued where it was felt that further relevant information might be uncovered.

6.2 What is a landmark?

Such a question may seem to have an obvious answer, since the word 'landmark' is used in everyday language. Nevertheless, landmarks have been defined in several different ways within the background literature. Such a range of definitions provides insight into how such objects are viewed by professionals such as psychologists, geographers, urban planners, etc. Several authors have placed an emphasis on landmarks as well-known objects within large-scale environments (e.g. Golledge, 1993; Kaplan, 1976). In such definitions, the stress is on the characteristics of landmarks that make them memorable, a concept referred to as *distinctiveness*, as opposed to the attributes of an individual. As such, relevant studies have primarily been conducted by geographers and urban planners.

Other researchers have stressed the divergent roles that landmarks play within people's mental representations, or cognitive maps, of the environment. This may be in relation to their significance in the learning process for new environments (Siegel & White, 1975), the distorting effects they can have on an individual's mental representation of an area (Tversky, 1992), their function as reference points or nodes (Sadalla, Burroughs & Staplin, 1980), or their potential as cues for orientation and wayfinding tasks (Tlauka & Wilson, 1994; Sholl, 1992). Such perspectives are typically those adopted by environmental psychologists.

6.2.1 Landmarks as distinctive objects

In her oft-quoted paper, Kaplan (1976, p.42) defines a landmark as, "a known place for which the individual has a well formed representation" . She outlines two overall theoretical factors that lead to a place or an object acquiring landmark status. Firstly, the frequency with which one has contact with the object or place, and secondly, its distinctiveness. She hypothesises three types of distinctiveness - taken as a whole, the factors highlight the fact that there are both objective and highly subjective components in regard to landmarks:-

(1) *Visual distinctiveness* (a factor stressed in the influential work of Lynch, 1960). This factor is purely sensory in nature and depends on attributes of the landmark that discriminate it from the surrounding environment (e.g. shape, size, colour). Therefore, this is a predominately objective quality. An example of a landmark with high visual distinctiveness would be a tall tower block in an area of few buildings of similar height.

(2) *Inferred distinctiveness.* In contrast, this factor has both experiential and cognitive aspects. For a landmark to possess inferred distinctiveness, an individual must know something about its structure or form that makes it stand out in relation to the surrounding region. Conversely, this attribute of a landmark suggests a person must know what is ordinary or usual (both generally and specific to an area). Examples of landmarks that may hold inferred distinctiveness would be a bridge of a different design from others in an area, or an old-style telephone box.

(3) *Functional distinctiveness.* This factor concerns the particular salience that a landmark may have for an individual or the function that it serves. Therefore, the object or place must have the status of a goal or subgoal. As such, this attribute is highly related to an individual's patterns of movement. Example landmarks in this category would be a Public House or Swimming Baths. Furthermore, an object used in route directions (e.g. get to the traffic lights, then turn right), may be viewed as a sub-goal in its own right, and, as a result, hold functional distinctiveness.

There have been some empirical studies which have addressed the components of distinctiveness with a view to establishing more specific attributes of memorable landmarks. Such knowledge is advantageous for urban planners, and architects who wish to design towns and cities containing landmarks, particularly buildings, that hold greater prominence for the inhabitants.

Appleyard (1969) conducted one such study. 320 inhabitants of a city were asked to recall buildings of the city, either verbally, on a sketch map, or as a description of a given route. Photos were taken of all the landmarks and used as the basis for determining relevant attributes of importance. Appleyard found that the buildings which were most often recalled were those of high use and/or important symbolic significance, those with a high size in contrast to their surroundings, and those with sharp, singular contours and bright surfaces. These findings have been replicated in a study by Pezdek and Evans (1979), but only where the building did not have semantic labels. If written labels were present on the buildings (e.g. The Library, The Black Bull Pub), they found that there was no relationship between the physical features of the building and memory. The authors argued that, in such cases, different coding strategies are used when committing the landmark to memory.

Other studies have revealed that the location of landmarks within the environment has a significant effect on its distinctiveness. Buildings close to important junctions or viewable from them (termed as proximate landmarks) are more frequently recalled as compared to distant landmarks (Allen, Siegel & Rosinski, 1978; Carr & Schissler, 1969). The most likely reason for the importance of this location factor is that proximate landmarks are of more use in everyday tasks, such as wayfinding.

However, observation of the literature on this topic suggests that there is still much to learn with respect to the attributes of distinctiveness. First and foremost, there have been relatively few empirical studies, despite its importance for urban planning. Furthermore, methodologies vary considerably between studies, and have been criticised in their use of sketch maps and/or small-scale models of environments (Evans, 1980; Kitchin, 1994). Finally, researchers have generally ignored the potential of social meaning and symbolism variables as components of distinctiveness. Instead, studies have concentrated on investigating the purely sensory components of distinctiveness, e.g. size, shape, contrast (Evans, 1980).

As noted by Peponis, Zimring and Choi (1990, p.557), "although the idea of distinctive may be at the core of what we mean by a landmark, the criteria of what characteristics produce distinction remain elusive and varied"

6.2.2 *The role of landmarks as components of cognitive maps*

Tolman (1948) is generally considered to be the first to propose that animals (including humans) "place learn" and do not just learn a series of overt responses to different stimuli. He argued that, following a sufficient period of environmental learning, we carry in our heads a spatial representation that is the mental analogy of a real map, a "cognitive map", as he called it. The term is now commonly referred to in the literature, and researchers have primarily concerned themselves with the content of cognitive maps, and how they are formed and manipulated (Dillon, Richardson & McKnight, 1990).

Landmarks as aids to the cognitive mapping process

The acquisition of environmental spatial knowledge (commonly referred to as the cognitive mapping process) is generally agreed by both cognitive psychologists and geographers to progress through several developmental stages. It is important to note that current thinking views all of these stages as points on a continuum, rather than discrete forms (Freundschuh, 1989). The overriding assumption is that, as one's knowledge of an area develops there are qualitative (e.g. knowledge of routes versus distinct points/objects) as well as quantitative (e.g. knowledge of more landmarks) changes, and, in addition, there is an advance towards an increasingly accurate world view (Dillon et al., 1990).

There are a large number of theories within the literature which describe the cognitive mapping process. Several theories view the knowledge of landmarks as an initial level which is achieved and then eventually replaced by a different level, such as knowledge of routes (e.g. Wickens, 1992; Siegel & White, 1975). People who possess landmark knowledge orient themselves exclusively by highly salient visual cues within the environment. Furthermore, in such theories landmarks are felt to form the skeletal frame of reference around which to build other levels of knowledge.

In comparison, other authors believe that landmark knowledge is constantly being added to throughout the knowledge acquisition process and hence aids in the developmental process at all levels of knowledge (e.g. Freundschuh, 1989; Hirtle & Hudson, 1991): For instance, a landmark may originally function as an object on its own in space. At a later time, the same landmark may act as a place on a route, and then later still the landmark may serve as a point where a number of routes cross.

An alternative viewpoint is expressed by Kuipers (1978), who describes the initial process of acquiring large-scale environmental information in terms of view-action pairs. As a person progresses through an environment they will observe views and perform actions. A view is defined as the total of all sensory experiences (predominately visual), at a point on a route, and oriented in a particular direction. A known route can be seen as a collection of view-action pairs stored in long-term memory. A prevailing reason for the importance of landmarks in navigation can be placed within this model, since inherent qualities of landmarks within the environment may help to form a greater association between a particular view and action respectively.

It is clear in these descriptions of theory that landmarks form a major part of a person's organisational framework, and are therefore very important in the development of cognitive maps. Indeed, several empirical studies have proved the benefits of landmarks on the cognitive mapping process. For instance, Evans, Skorpanich, Gärling, Bryant and Bresolin (1984) conducted a laboratory-based experiment in which subjects viewed a series of slides of a route five times in total. Following the viewing, subjects were given a variety of memory-based tests. Evans found that the addition of scenes with prominent landmarks facilitated knowledge. The effect was strongest for an environment which had a non-grid structure, suggesting that landmarks may have a greater role for learning in more complex environments. Allen et al. (1978) conducted a series of three experiments which provided very similar results to those of Evans, establishing, once again, the extent to which people use landmarks to organise their cognitive representation of a route.

Landmarks as distorting elements

There is considerable empirical evidence of systematic and predictable patterns of distortion in people's cognitive maps of the physical environment. These irregularities may lead to rotation and alignment errors, inaccuracies in perceived topological relations, e.g. the squaring of non-perpendicular intersections, or imprecise distance judgements (McDonald & Pellegrino, 1993). It is with respect to this latter task that landmarks have primarily been found to act as distorting elements.

In many cases distortions arise due to the cognitive organising principles people impose in order to store information more efficiently (Tversky, 1992). The concept of landmarks acting as reference points in cognitive maps is one such principle used to facilitate memory (Allen et al., 1978; Sadalla et al., 1980; Sholl, 1992). For such prominent landmarks other non-reference points are defined cognitively in terms of the landmark's position. In the words of Sadalla et al. (1980, p.516), such landmarks "provide an organisational structure that facilitates the location of adjacent points in space".

To investigate this theoretical statement empirically, Sadalla et al. asked students to estimate distances between different known campus locations using either a familiar landmark or a relatively unknown building as a reference point. The landmarks led to asymmetries in distance estimations, since, when a landmark served as a reference point, ordinary buildings were judged to be closer to it than vice-versa. In other words, they found that, in cognitive terms, landmarks draw other objects closer to them. A similar result has been found by Holding (1992).

Sadalla et al. also explored which attributes of an object or place within the environment lead to it becoming a spatial reference point. They found that landmarks which operate as reference points have high familiarity, tend to be large (so that they dominate the surrounding area), are visible from a distance, and are culturally significant. The importance of the familiarity characteristic is borne out by a study by Briggs (1973), which found that the relative familiarity of landmarks along a route affected distance judgements.

A further way in which landmarks induce distortions occurs when people estimate distances along a route. A number of studies have revealed that errors in estimating total route distance are a linear function of the number of landmarks along the route (Byrne, 1979; Thorndyke & Goldin, 1983). Researchers have also found similar findings in relation to the number of turns along a route (Thorndyke, 1981, Sadalla & Magel, 1980). The distortion is considered to arise because people employ a simplifying heuristic of segmenting a route using category boundaries, such as landmarks or turns.

It has been noted earlier that there are both objective and subjective aspects relating to defining what constitutes a landmark. The personal, highly subjective, attributes of landmarks have also been found to lead to errors in distance judgements. For instance, Smith (1984) investigated the effect of the pleasingness (or general liking) one has for various landmarks on distance judgements. Subjects were shown a scaled map with named landmarks (e.g. sex shop, church, dentist, railway station, public toilets), and asked to study it. The map was then taken away, and subjects were asked to recall distances between landmarks and rank the landmarks in order of general liking. Accuracy of distance judgements was found to increase as ratings of landmark liking increased. The author cites a number of reasons as to why this result may have occurred, including the perceived consequences of being at a disliked landmark.

6.3 Relevance of background issues

The review of the literature within non-human factors disciplines discovered a number of viewpoints of relevance to the use of landmarks by route guidance systems. For the most part, the background theory and empirical studies backed up the work conducted by human factors researchers, i.e. that considerable benefits may arise from the presentation of landmarks by route guidance systems. Moreover, the review was able to provide an indication as to why such advantages exist, which may be summarised by the following three points:-

(1) Since landmarks appear to be an important aspect of drivers' cognitive maps, it seems reasonable to assume that the presentation of an appropriate landmark by a route guidance system may help to reduce a driver's navigational uncertainty. That is, a landmark can help a driver to establish where, within the environment, a decision is required. Indeed, considering landmarks are generally such well-known objects, one might hypothesise that a route guidance system which utilised landmarks would match drivers' expectations, thereby allowing easier and faster navigational decision making. The review of the human factors literature (Chapter 2) revealed that there had been little work providing empirical evidence for these advantages (only Bengler, Haller & Zimmer, 1994).

(2) Considerable evidence exists to show that landmarks play an important part in the environmental learning process. As a consequence, it is feasible that the presentation of landmarks by a route guidance system might also aid in the development of a driver's cognitive map of an area. An important related issue should be raised at this point regarding the long-term use of route guidance systems, one that has attracted some comments, but, to date, no empirical research. Certain researchers (Jackson, 1995; Bengler et al., 1994) have expressed concern that the use of simple turn-by-turn route guidance systems will, over time, prevent drivers from forming a cognitive map of the environment. As a result, there is a danger that the navigation task as experienced when using route guidance systems will never become automatic, that is, not requiring an external information source. In other words, it is quite possible that, in the long-term, drivers will come to rely too heavily on route guidance systems. The background theoretical and

empirical literature suggests that this concern may be abated via the presentation of appropriate landmarks.

(3) The review revealed that there are certain, highly personal aspects that lead to an object or place within the environment achieving landmark status. On the basis of this evidence, one would expect that the presentation of landmarks by a route guidance system would give rise to considerable advantages with respect to the subjective aspects of system usability. Indeed, the human factors review generally revealed such acceptability benefits above all others (e.g. Green et al., 1993a; Alm et al., 1992).

The final output of the background review of relevance to human factors work concerns the distortions that arise within cognitive maps. Such inaccuracies have potential implications for the validity of human factors studies which have used individual's cognitive maps to elicit the information that should be presented by route guidance systems (see studies by Alm, 1990; Obata et al., 1993). When providing route directions, a number of systematic errors may be predicted to arise, either in relation to junction descriptions, distance estimations, and, of most relevance here, the choice of 'good' landmarks. The review revealed that distortions can occur as a result of the subjective appeal of a landmark. A concern expressed at this stage is whether landmarks extracted from a cognitive map to help people find their way will be biased by subjective landmark attributes rather than by purely objective components. Indeed, there does seem to be a common sense argument here, since people generally do give directions based on landmarks that are appealing to them. A typical example can be seen in the person who provides directions based purely on pubs or particular types of shops.

However, it must be noted that the background review did not reveal any studies addressing this effect in relation to the specific example of providing directions. Therefore, it must be borne in mind that, without direct evidence, such concerns are purely conjectural.

Chapter 7: The choice of landmarks for use within a route guidance system

7.1 Introduction

Previous chapters have shown several benefits for the use of landmarks (e.g. traffic lights, post-boxes, parks, monuments) within route guidance systems. Drivers, particularly females, rate landmarks favourably for use in urban areas, and actively seek out such prominent objects for use in the navigation task. The brief review reported in the previous chapter revealed some reasons as to why this is so: landmarks constitute fundamental components of people's cognitive maps, and play an important part in the environmental learning process.

If the ultimate benefits of landmarks are to be realised, it will be important that appropriate landmarks are selected and specified by map database providers*. The use of 'poor' landmarks, for instance those which are difficult to find and/or uniquely identify, may increase driver workload and reduce driving safety.

Previous human factors research has addressed the 'landmark' issue from one of two perspectives: either lists of the most commonly reported landmarks have been drawn up from a sample group of drivers (e.g. Alm, 1990; Akamatsu et al., 1994); or a limited number of landmarks have been evaluated within a prototype route guidance system (e.g. Alm et al., 1992; Bengler et al., 1994; Green et al., 1995). As pointed out in Chapter 2, all of these studies have been conducted outside the UK, and, given environmental differences, their recommendations may not be directly applicable to this country.

More generally, beyond some casual comments (e.g. Alm, 1990; Akamatsu et al., 1994; Green et al., 1995), there has been no investigation of the basic characteristics that make particular landmarks appropriate for navigation. Knowledge of this kind will be important in the development of a method of

* The role of map database companies will be explored in Chapter 9 (section 9.5.1).

obtaining potentially useful landmarks for inclusion in map databases that cross country borders, e.g. for a pan-European map.

7.2 Aims

This study had two aims: firstly, to produce a list of landmarks that could potentially be used by a route guidance system within the UK. Secondly, the study had the objective of identifying the salient characteristics or attributes of landmarks that will be of importance when choosing landmarks for use within a route guidance system.

In addressing this second aim, a first step towards developing a method which could potentially be applied to different environments was made. Such a context-independent technique would allow a set of landmarks to be established for use within other countries as well as in the UK.

7.3 Experimental rationale

7.3.1 Overall design

There were several requirements which the experimental method to be used for this study had to take into account:-

(1) The procedure should not rely on an individual's cognitive map of an area. As discussed in Chapters 2 and 6, several researchers have chosen 'ideal' landmarks on the basis of the specific knowledge that drivers have of a particular environment. Such landmarks may not be optimal for the general driving population due to the inherent, personal biases within cognitive maps.

(2) A criticism of previous research is that the results are wholly dependent on the environment in which the study was carried out. This study aimed to be context-independent, that is, to understand what characteristics of a landmark make it appropriate for navigation purposes, regardless of the environment in which it is located.

(3) It was important that the method was, as far as possible, independent of the means of presenting the landmarks. The study aimed to focus on the attributes of landmarks within the environment, and not the presentation of such information within a route guidance display.

(4) It was important that the method accounted for the context of the driving and navigating task, i.e. that safely controlling the vehicle is the primary driving task, and the processing of navigation information (both inside and outside the vehicle) is secondary.

Based on a consideration of the above points, it was felt that a subjective assessment of landmarks by subjects would be the most appropriate approach for this study. Subjects would rate a number of landmarks against potential environmental attributes (e.g. visibility, uniqueness). Such a method would rely on the general knowledge that drivers have for using landmarks for wayfinding (i.e. their global schemata), and not on their specific cognitive maps. It was realised that, although this approach satisfied the requirements in points 1, 2 and 3 above, task context would be poor in a study such as this. Consequently, the framework utilised for addressing the choice of landmarks (see 7.3.2 below) was deliberately chosen so as to recognise that the workload imposed by the processing of navigation information must be minimal.

7.3.2 Framework for choosing landmarks

A conceptual framework was developed by the author, so that the task of using landmarks in a driving and navigating context could be considered. It was intended that this exercise would generate a list of environmental attributes of landmarks that influence their effectiveness for navigating purposes. The empirical study (described in 7.4) would then be used to establish which of the attributes were likely to be of greatest importance, and hence should be taken into account when choosing landmarks for presentation by a route guidance system.

The framework (Figure 7.1) utilised an information processing perspective, and was adapted from more generic models (see, for example Wickens, 1992), based on a consideration of the use of landmarks for navigating. Several distinct processing stages were proposed, whereby a landmark is firstly detected and identified (both within the environment and a 'system' representation), and is then used for the purposes of making a specific navigational decision (i.e. where do I turn?).

As noted earlier, the focus of this study was the pertinent characteristics of the landmarks themselves, rather than their on-screen or spoken presentation. Therefore, although the stages required for processing the system representation of the landmark are included in the framework, they were not considered in this study. Chapter 2 outlines some key issues that have to be addressed regarding the design of HMIs which include landmarks (e.g. standardised iconic representations).

Attributes of landmarks within the environment that would potentially affect the ease of processing (and hence driver workload) for each of the different stages were identified, based on three distinct sources:

- Observation of comments made by several authors in the literature (Chapter 2) concerning characteristics of 'good' landmarks
- The data reported in Chapter 4's questionnaire survey, regarding drivers' reasons for preferences or dislike of landmarks for navigation
- A consideration by the author of additional factors that would conceivably have a bearing on the ease with which information is processed at each of the stages

What follows is a brief description of each of the processing stages within Figure 7.1, and the attributes of landmarks that are considered to be potentially relevant:

1) *Decision to look for the landmark* - In response to the presentation of information by the route guidance system, a decision has to be made by the driver to search for the landmark within the environment. There are no attributes of landmarks within the environment that are considered to have an effect at this stage.

2) *Landmark detection* - The detection of the landmark largely consists of the stimulation of the sensory-receptors. It is assumed that the primary sense used in this process is the visual modality. Fundamentally, in order for

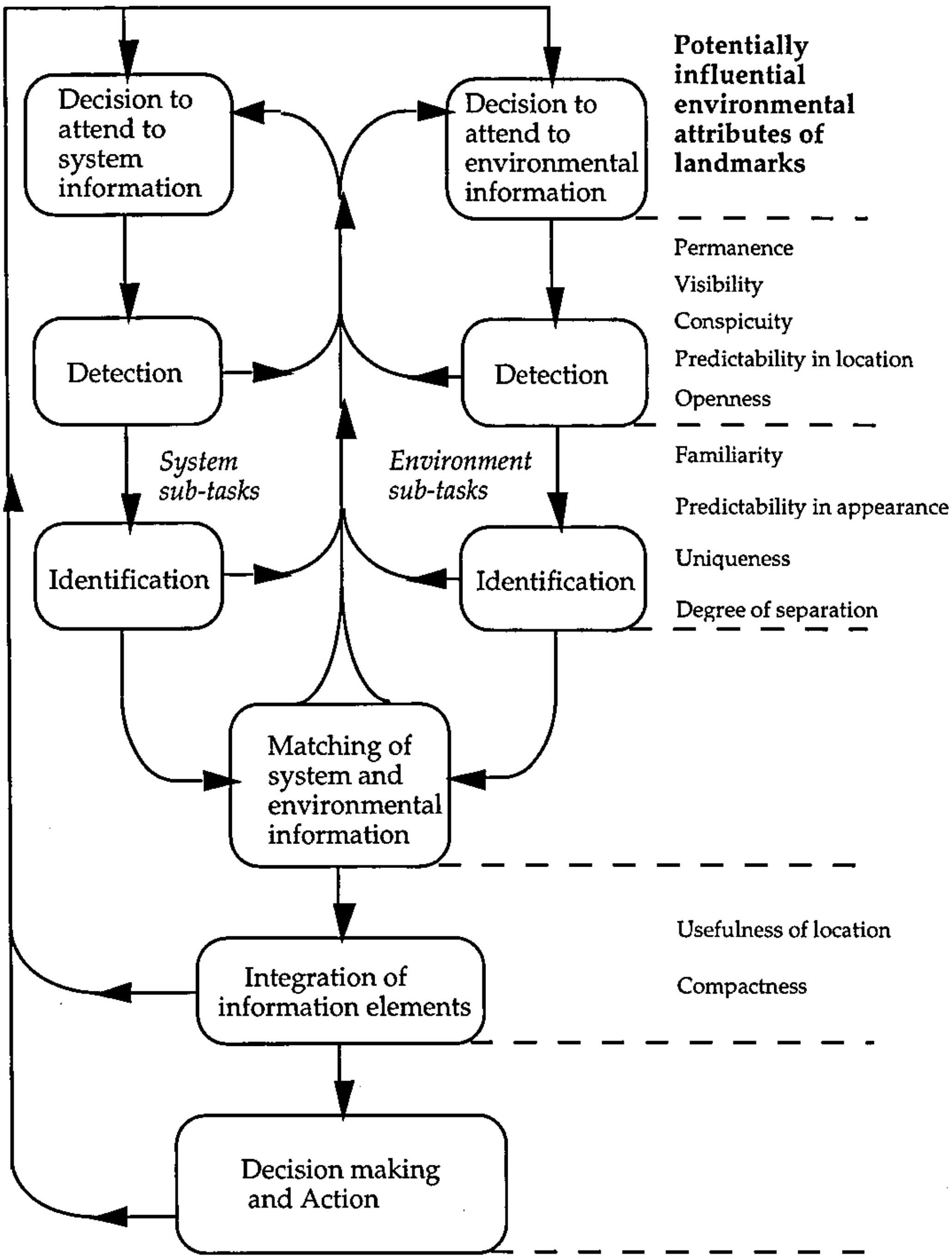


Figure 7.1 - An information processing framework for the use of landmarks in the navigation task

detection to occur, the landmark must be present in the first place. It should also be of a size, shape and nature that it is normally clearly seen, will attract the attention of the driver, and must be physically located where expected. Finally, the landmark should not be obscured from view. In summary, the following attributes appear to be important:

- Permanence - is the landmark physically there?
- Visibility - is the landmark normally seen clearly?
- Conspicuity - does the landmark catch your attention?
- Predictability in location - do you know where to look for the landmark?
- Openness - is the landmark likely to be obscured so that it cannot be seen?

3) *Landmark identification* - Once the landmark has been detected, it must be identified as one particular object or a member of a class of objects. The landmark must not be confused with objects which may be other instances of the same object or other objects that are fundamentally different. The following attributes would appear to be influential at this stage:

- Familiarity - does the driver recognise the landmark as a known object?
- Predictability in appearance - does the landmark have an expected appearance?
- Uniqueness - does the landmark (or class of landmarks that have a generic name) have an appearance that is unique enough so that it is not easily mistaken for other similar (but different) objects or classes of objects?
- Degree of separation - are examples of this landmark usually sufficiently far apart from each other in order that they will not be confused with each other?

4) *Match system information to environmental information* - The driver must make a one-to-one match between the identified landmark within the environment, and that represented by the route guidance system. The ease by which this stage is accomplished will depend on the degree of similarity in the mental models that the driver has of the landmark, based on the previous stages. Therefore, there are no environmental landmark attributes considered to be important at this stage.

5) *Integration of information elements* - Once the real world landmark and system representations are matched, the landmark has to be used to aid the

driver in making a navigational decision, e.g. which is the correct turning? Other information will presented by the route guidance system (e.g. direction, road layout and distance information), and then integrated together by the driver, to allow such decisions to be made. The following landmark attributes will have an influence at this stage:

- Usefulness of location - how useful is the location of the landmark in terms of being easily used to convey navigational information (carry on, make a manoeuvre etc.)?
- Compactness - is the landmark appropriately compact (in relation to the junction size and vehicle speed) to allow it to be accurately related to a specific turning?

6) *Make and execute navigational decision* - Once the matching of the system and real world landmark has been combined with other necessary information, a navigational decision can be made and carried out. No landmark attributes have an influence here.

In summary, eleven characteristics or attributes of landmarks have been identified as those most likely to influence the effectiveness of a landmark in a navigational context. The empirical study described in the remainder of this chapter will determine whether all these attributes are equally important, or whether they have differing degrees of influence over the effectiveness of a landmark in the navigation task.

7.4 Method

7.4.1 Subjects

Subjects were selected for this study on the basis of their perceived navigational abilities. As discussed in Chapter 2, Streeter and Vitello (1986) found some evidence to suggest that 'poor' navigators are unable to differentiate between good and bad landmarks for navigation, and rate all as equally effective. Streeter et al. also found that perceived navigational abilities correlated well with actual abilities. Therefore, since the ability to discriminate between landmarks was critical to this study, it was decided to only employ subjects who considered themselves to be at least "fairly good" at finding their way in an unknown area.

26 male and 10 female drivers, mean age 39 (SD=13.85, range 22 to 60) participated in this study. The subjects were predominately experienced drivers: they had held a full driving licence for an average of 20 years (SD=13.6, range 4 to 47); and had driven an average of 12,700 miles (SD=12,000, range 4,000 to 65,000) in the previous year. Subjects were also generally experienced in navigating, since 23 of the 36 subjects stated that they drove on their own in an unfamiliar area at least once a month. The remaining 13 subjects drove alone in an unfamiliar area once every two to six months.

7.4.2 Choice of landmarks

A total of 29 generic landmarks were rated by all subjects. These landmarks were the same as those used in Chapter 4, that is, based on a list of common landmarks considered by a separate group of human factor specialists to be of use in the navigation task.

7.4.3 Equipment and rating scales

The experimental ratings were carried out on a Macintosh™ computer utilising a program written specifically for this study. Each subject rated each landmark against each of the 11 attributes identified in the previous section, on a 50 segment scale, with semantic anchors of "low" and "high". 50 points were chosen, based on the display size and the need to show a clearly 'lit' segment for feedback to subjects.

The scale was devised so a rating at the lowest end of the scale represented a value of 1, and a rating at the highest point on the scale represented a value of 50. The subject highlighted a point on the scale by moving the computer cursor with the mouse, and this point was then selected by pressing the mouse button. The rating on the scale was logged by the computer in the appropriate cell in a results matrix. A print out of a sample computer screen as viewed by the subjects is shown in Appendix 7A.

7.4.4 Pilot trials

Pilot trials were carried out to ensure there was unlikely to be any ambiguity in attribute definitions and the labels attached to landmarks. The introductory information, and final attribute definitions and subject instructions are included in Appendix 7B.

7.4.5 Procedure

Rating against landmark attributes

The landmarks were divided into two sets (of 15 and 14 landmarks) to enable a break in the experiment. The first set of landmarks was rated against the first of the 11 attributes. When all of that set of landmarks had been rated against the first attribute, a second attribute was presented and the same set of landmarks were rated against this second attribute and so on until all of one set of landmarks had been rated against all 11 attributes. In this way, the subject was only required to consider one attribute and its accompanying definition at a time. It was assumed that the subjects were more familiar with the landmarks than the attributes, and so would find it easier to consider each attribute than each landmark at a time. The order of presentation of the landmarks was randomised for each rating against an attribute. The order of presentation of the 11 attributes was also randomised for each session.

The subject was given a short break, and the whole procedure was carried out with the second set of landmarks. The order in which subjects rated the two sets of landmarks was fully balanced.

Rating against overall scenario

At the end of each of the two sessions, each landmark was given an overall rating on a 50 segment scale with semantic anchors of "difficult" and "easy", based on the following task scenario:-

> "Imagine you are driving in an unfamiliar area and can use landmarks to help you establish where to turn. How easy/difficult will it be to find the correct turning using the following landmark?"

It was realised that a landmark could be used for a number of different aspects of the navigation task (e.g. to enable orientation, or to confirm that the driver is on the correct route). It was decided in this study to concentrate on what is unquestionably the most fundamental aspect of the navigation task, locating a decision point. When approaching a manoeuvre the demands of driving can be high (slowing down, increased traffic etc.), and, it is therefore of paramount importance that sources of additional workload are minimised.

At the end of the experiment, each subject was paid for their participation.

7.5 Results

7.5.1 Descriptive Analysis

An analysis of the distributions in subjects' ratings for the landmark attributes revealed that several of the datasets were negatively skewed. Such distributions resulted when attributes of particular landmarks were generally rated towards one end of the scale. As an example, for the attribute of Visibility, the skewness value for Bus/Coach station was -0.50, where 0 would indicate a normal distribution.

This result was not unexpected, since if a particular landmark attribute is generally rated at one end of the rating scale, there will be a cluster of data points at this extremity, but there will also be several outliers which produce an extended tail to the distribution. The use of finite rating scales cut off an equivalent tail to the distribution at the end of the scale. The appearance of outliers could be due to several reasons: a subject may have misunderstood the attribute definition; misread or misunderstood the landmark description; they may have simply inadvertently clicked the mouse at the wrong point on the scale; or they may have genuinely felt differently from the other subjects.

With skewed data such as these, it is inappropriate to use mean values as an indication of central tendency, as these would give undue weight to the outliers. Therefore, median values were calculated for the ratings for each of the landmark attributes and for the overall rating.

Attribute scores

Table 7.1 shows the five top and bottom scoring landmarks for each of the 11 attributes, based on the median scores. The table also shows the inter-quartile ranges as a measure of the dispersion in the results. The full set of results (including means and standard deviations) are shown within Appendix 7C.

Name of attribute	Top 5 landmarks	Med	IQ range	Bottom 5 landmarks	Med	IQ range
Permanence	River	47.5	44-50	Petrol Station	30.5	26-43
	Brow of a hill	46	40-48	Bus stop	24	16-34
	Monument	44.5	41-48	Shop/Restaurant	22	15-31
	Church	43	38-47	Advertising Hoarding	22	10-31
	Wood/Forest	43	38-47	Repairs garage	21	13-33
Predictability in location	Traffic lights	47	44-48	Church	16.5	12-31
	Pelican crossing	46	40-48	River	15	6-28
	Bridge over road	43.5	23-46	Wood/Forest	13.5	6-24
	Road sign/signpost	43	36-46	Monument	12.5	7-24
	Street name signs	42.5	31-46	Railway line	12.5	6-20
Conspicuity	Pelican crossing	45	37-48	Telephone box	16	8-26
	Traffic Lights	43	31-48	Railway line	14	7-22
	Superstore	37.5	30-42	Bus stop	13	7-22
	Petrol station	36.5	30-41	Postbox	12.5	8-31
	Advertising Hoarding	35.5	24-41	Street name signs	12.5	4-25
Visibility	Traffic lights	41.5	36-49	Railway line	17	10-31
	Bridge over road	41	33-46	Dip in road	13	6-29
	Pelican crossing	41	37-46	Postbox	12	5-18
	Multi-storey car park	40.5	31-46	Street name signs	11	5-21
	Church	39.5	32-43	Bus stop	10	5-19
Openness	Traffic lights	44	33-47	Railway line	22.5	8-30
	Bridge over road	43.5	36-47	Telephone box	14.5	8-31
	Multi-storey car park	42	38-47	Postbox	11	7-21
	Wood/Forest	42	38-46	Bus stop	10.5	7-18
	Pelican crossing	41	27-47	Street name signs	9	3-15
Familiarity	Traffic lights	47.5	45-50	Shop/ restaurant	35.5	29-40
	Telephone box	46	41-48	Brow of a hill	34.5	28-41
	Postbox	46	41-48	Monument	30.5	22-40
	River	45.5	40-48	Dip in road	26.5	17-39
	Petrol station	45	39-47	Repairs garage	23	13-35
Predictability in appearance	Traffic lights	49	46-49	Factory	26	12-32
	Pelican crossing	47.5	42-49	Shop/ restaurant	23	13-30
	Postbox	45.5	39-48	Repairs garage	21	12-30
	Telephone Box	44	37-47	Monument	19	8-33
	Bridge over road	44	33-48	Dip in road	18	11-34

Table 7.1 - Median (Med) scores and Inter-quartile (IQ) ranges for each of the 11 landmark attributes (1 = Low; 50 = High)

Name of attribute	Top 5 landmarks	Med	IQ range	Bottom 5 landmarks	Med	IQ range
Degree of separation	Railway station	43	39-47	Road sign/signpost	19	8-34
	Factory	42	34-47	Dip in road	16.5	6-27
	River	40.5	31-45	Street name signs	17	5-38
	Monument	40.5	35-46	Bend in road	16.5	6-25
	River	40	31-45	Bus stop	14	8-29
Uniqueness	Pelican crossing	41.5	21-47	Road sign/signpost	22.5	10-37
	Bridge over road	41	26-47	Dip in road	19	8-31
	Monument	41	36-47	Bend in road	17	8-26
	Traffic lights	38	11-48	Bus stop	16	9-32
	Church	35.5	23-40	Repairs garage	15	9-20
Usefulness of location	Traffic lights	46.5	43-49	Dip in road	28.5	14-40
	Road sign/signpost	44.5	35-47	Repairs garage	24.5	21-32
	Pelican crossing	44	40-48	Wood/Forest	18	8-29
	Street name signs	44	35-48	Railway line	16.5	10-25
	Postbox	41	32-45	River	14.5	6-30
Compactness	Traffic lights	47	42-49	Factory	24.5	18-35
	Postbox	47	40-48	Multi-storey car park	24.5	16-36
	Telephone box	46.5	40-48	River	12	6-27
	Street name signs	45.5	37-48	Railway line	11	4-23
	Road sign/signpost	45.5	40-48	Wood/Forest	7.5	4-18

Table 7.1 (continued) - Median (Med) scores and Inter-quartile (IQ) ranges for each of the 11 landmark attributes (1 = Low; 50 = High)

Overall rating scores

A median score and inter quartile range was calculated for each of the landmarks based on the overall ratings given by subjects. The results of this analysis are shown within Table 7.2.

Variability in ratings

To indicate how the ratings provided by the subjects varied for each attribute and for the overall ratings, mean scores were calculated based on the median values for all landmarks. The results of this analysis are shown in Table 7.3. This table also shows, for each of the attributes and the overall rating, the mean of the standard deviations for each of the landmarks. This was carried out to give an indication for each of the attributes and for the overall rating, of (a) how highly the sample of landmarks were rated, and (b) the variability of subjects' ratings.

Top 15 landmarks	Median overall rating	Inter-quartile range	Bottom 14 landmarks	Median overall rating	Inter-quartile range
Traffic lights	47	40-48	Factory	35	23-39
Pelican crossing	44	38-47	Bus/coach station	34	28-38
Bridge over road	42	35-47	Telephone box	34	22-43
Hump-backed bridge	41	33-44	Postbox	33	24-42
Petrol station	40	30-42	School	33	25-39
Monument	39	31-44	Multi-storey car park	32.5	28-37
Superstore	39	29-44	Bend in road	27	16-38
Street name signs	38.5	22-46	Brow of a hill	26.5	16-39
Railway station	38	32-44	Repairs garage	26.5	19-34
Church	37	33-44	Bus stop	25.5	16-36
Road sign/signpost	36.5	30-42	Dip in road	23	12-32
Public House	36.5	35-40	River	23	11-33
Advertising hoarding	36	29-42	Wood/Forest	23	11-30
Shop/restaurant	35.5	25-40	Railway line	17.5	12-31
Cinema	35	29-39			

Table 7.2 - Median overall rating and inter quartile ranges for subjects' overall ratings (1 = Difficult; 50 = Easy)

Landmark attribute/ Overall rating	Mean of median scores for each landmark	Mean of standard deviations for each landmark
Permanence	36.3	10.86
Predictability in location	29.0	12.99
Conspicuity	27.9	12.23
Visibility	29.8	11.65
Openness	32.1	10.86
Familiarity	39.9	9.99
Predictability of appearance	34.5	11.50
Degree of separation	29.6	12.53
Uniqueness	29.9	13.74
Usefulness of location	34.7	11.01
Compactness	33.7	11.28
Overall rating	33.7	11.23

Table 7.3 - Mean of median scores and mean of standard deviations for each landmark - for each of the landmark attributes and overall ratings scenarios

7.5.2 *Correlation analysis*

In the next stage of the analysis, correlation statistics examined the relationships between the different attribute scales and between the attribute scales and the overall ratings (see Table 7.4). This analysis was based on the median values obtained for each of the 29 landmarks across the 36 subjects. This strategy of collapsing subjects' data into a single score for each landmark prior to conducting correlations has also been carried out by Sadalla, Burroughs and Staplin (1980) when investigating the features of landmarks that dictate their prominence within peoples' cognitive maps.

Note that for ease of reading, this table only codes significant results in terms of the 5% and 1% level. Many of the correlations were associated with significance levels of less than 1%.

7.5.3 *Further analysis*

It is clear from the above inter-correlations between the different attributes that a degree of redundancy existed in the data. Therefore, it was decided to carry out a formal factor analysis in order to group attributes into a reduced number of underlying factors prior to a regression analysis. It was hoped that this supplemental work would provide some further indications as to the characteristics of 'good' landmarks. The following points provide a brief summary of the key results - further details can be found in Appendix 7D.

1. It was evident that subjects' ratings for the Permanence attribute were not related to those for any other attributes (see Table 7.4 above). For this reason, it was decided *not* to include permanence in the factor analysis.

2. A four factor solution was suggested by the data, accounting for 92% of the total amount of variance (i.e. the original ten attributes could be collapsed to four underlying factors). Certain attributes had high correlations (loadings) for particular factors. Table 7.5 summarises these principal attributes, and also provides tentative labels to the underlying factors.

	P	PL	C	V	O	F	PA	DS	U	UL	CP	OR
Permanence (P)	/	-.01	.20	.31	.32	.16	.09	.25	.33	.09	-.10	.18
Predictability in location (PL)		/	.01	-.21	-.24	.52 **	.73 **	-.54 **	.01	.74 **	.58 **	.38
Conspicuity (C)			/	.91 **	.86 **	.24	.21	.44 **	.68 **	.23	-.08	.66 **
Visibility (V)				/	.96 **	.16	.08	.53 **	.58 **	.01	-.31	.47 *
Openness (O)					/	-.02	-.07	.51 **	.47 *	-.13	-.45 *	.34
Familiarity (F)						/	.82 **	-.11	.43 *	.78 **	.49 *	.55 **
Predictability of appearance (PA)							/	-.23	.45 *	.80 **	.65 **	.56 **
Degree of separation (DS)								/	.53 **	-.24	-.41 *	.26
Uniqueness (U)									/	.45 *	.29	.81 **
Usefulness of location (UL)										/	.73 **	.73 **
Compactness (CP)											/	.47 *
Overall Rating (OR)												/

* - p<0.05

** - p<0.01

Table 7.4 - Results of correlation analysis

Factor 'label'	**Principal attributes included**
Visibility	Openness, Visibility, Conspicuity
Location	Compactness, Usefulness of location, Predictability of location
Expectation	Predictability in appearance, Familiarity
Uniqueness	Degree of separation, Uniqueness

Table 7.5 - Summary of principal attributes included within the 4 factors

3. In a preliminary examination of the data utilising scatterplots, it was revealed that three particular landmarks, wood/forest, river, and railway line, could be treated as outliers. These were therefore removed from the subsequent regression analysis.

4. A stepwise multiple regression analysis assessed the degree to which a combination of the factorised attribute scales could account for variation in the overall ratings. The specific contribution of each of the factorised scales to the prediction of overall rating can be observed in the following table.

Factor	Coefficient	R^2 added	R^2 -cumulative	Sig level
Location	0.70	0.33	0.33	$p<0.005$
Visibility	0.40	0.44	0.78	$p<0.0001$
Uniqueness	0.22	0.11	0.89	$p<0.0005$
Expectation	/	0	0.89	$p=0.45$

Table 7.6 - Results of stepwise regression analysis

As can be seen, Location, Visibility and Uniqueness (in that order) are most related to the overall ratings given for landmarks. These three factors account for 89% of the variance in the overall ratings of landmarks.

7.6 Discussion

7.6.1 The preferred set of landmarks

Based on the overall ratings made by subjects, the following are the most suitable landmarks for use by route guidance systems in the UK: traffic lights, pelican crossing, bridge over current road, hump-backed bridge and petrol station. Comparing these landmarks with those reported in previous studies (see Table 2.3 in Chapter 2), one can see that traffic lights, bridges over the current road and petrol stations are consistently included in results as 'good' landmarks. This finding reiterates the view expressed in Chapter 5, that at the top end of the scale there are some generic landmarks that map databases could contain which will be appropriate across different environments. Nevertheless, the fact that two more idiosyncratic landmarks (i.e. pelican crossing and hump-backed bridge) are included in the top five for the UK reiterates the view that a means of determining the salient characteristics of good landmarks is required.

Observation of the highest scoring landmarks in Table 7.2 shows that the most appropriate landmarks were generally those which are part of the road infrastructure (i.e. the designed environment). In contrast, the lowest scoring landmarks were those which are part of the natural environment (e.g. woods, rivers). In addition, there was a link to the degree of dispersion in subjects' ratings, since higher scoring landmarks were generally associated with less variability than were lower scoring landmarks. These results are not surprising, given that many of the infrastructure landmarks (e.g. traffic lights, pelican crossing) have been deliberately designed so as to possess many of the attributes considered within this study, e.g. high visibility, strong predictability.

Observation of the inter-quartile range values in tables 7.1 and 7.2 indicate that subjects varied in their ratings of landmarks, both within and between landmarks. The variability in subjects' ratings for a given landmark may reflect the degree to which the quality of that landmark varies from one situation to another. As an example, the variability in Visibility ratings for churches (IQ range between 32 and 43) would suggest that drivers consider some instances of that landmark to be less appropriate than others. As a consequence, it is felt that effective landmarks (within a class) should not only rate highly on the overall scale, they should also have minimal variability in order to be reliable "good" landmarks. Variability may also have arisen as a result of the chosen methodology, and this is discussed in section 7.6.5.

As a further point, it is worth mentioning that in practical terms, even for a good generic landmark (i.e. based on class), there will be instances of its occurrence which will negate its effectiveness in the navigational task, e.g. a road sign which is obscured by vegetation, a monument which is offset from the road, etc. This suggests the need for the identification of the effectiveness of individual landmarks in the environment for use in a route guidance system. One potential method may be to employ an expert assessment of landmarks in the field. In order for this expert assessment to be viable, a landmark ratings system, which is sufficiently simple to enable quick but accurate ratings of the likely effectiveness of each landmark is required.

One must remember that the above findings are still based on subjective ratings, and on-road testing is required to establish the performance-related benefits of different landmarks. The work reported in Chapter 8 investigates this very issue, utilising a range of different landmarks (traffic lights, telephone box, church, petrol station, bridge over road, bus stop, post box, park, and shop).

7.6.2 *Outlier landmarks*

It was apparent from the data that subjects were less consistent in their rating of three landmarks: wood/forest, river and railway line, in contrast with the others within the sample. As a result, such landmarks were removed from subsequent analysis. It is possible that such differences arose because subjects held two distinct mental models of these landmarks, which they utilised for different attribute ratings. For instance, when considering the 'detection/ identification' attributes, subjects may have applied a mental representation of the whole object, for example, an image of a river. In contrast, when contemplating the use of the landmark for locating a turning, subjects may have conceptualised the point at which the object interacted with the road infrastructure, for example where a river was traversed by a bridge.

The implications of this result are that continuous objects, such as rivers and railway lines, cannot be referred to solely as such within a route guidance system HMI (e.g. turn left after river). They will need further definition (e.g. turn left after going over river) to avoid possible driver confusion.

7.6.3 *Attribute correlations*

As shown by Table 7.4, ratings on many of the landmark attributes were found to be highly correlated with one another, most likely as a result of either one of, or a combination, of the following influences:

(1) Subjects not being able fully to differentiate between particular attributes (as a result of semantic ambiguities in landmark and attribute definitions), and thus giving ratings for each attribute based on an overall view. This methodological point will be discussed in more detail later (section 7.6.5).

(2) Naturally strong relationships between these attributes for landmarks within the environment. A salient example is the particularly strong correlations arising for the detection attributes of Visibility, Conspicuity and Openness. If a landmark was conspicuous (stood out from the background), it was also likely to be visible (observable from a distance). Openness could be linked to both Conspicuity and Visibility, since a conspicuous and visible landmark is (a) likely to be of such a size that it cannot be easily obscured (e.g. a Pub), and (b) it is likely to be an object so situated (perhaps intentionally) that it is not easily obscured (e.g. Traffic Lights).

7.6.4 What makes a landmark 'good'?

The model of the information processing steps associated with the use of a landmark within a route guidance system (Figure 7.1) served as a useful means of considering the factors that dictate 'good' and 'poor' landmarks for navigation. Furthermore, observation of the correlations between attribute ratings and overall ratings (Table 7.4) provides some indication as to the factors that relate to drivers opinions of a 'good' landmark. The five attributes that correlated most with overall ratings ($R>0.5$) were Uniqueness, Usefulness of Location, Conspicuity, Predictability of Appearance and Familiarity.

Although there were generally no surprises regarding inclusion in this list, it was slightly unexpected that Permanence did not correlate with overall scores, since the physical presence or otherwise of the landmark is undoubtedly of importance. It was felt that for overall ratings, subjects were assuming that the landmarks were actually present in the first place. This suggests that permanence should operate as an initial factor, such that a landmark must possess this characteristic prior to a consideration of any other attributes.

Unfortunately, the high inter-correlations between attribute scores negates any further conclusions that might be drawn, and, as a result, it was necessary to conduct a factor and regression analysis. Although speculatory, this analysis suggested that the three factors which most dictate whether a landmark will be a suitable choice for a route guidance system are:

- *Location* - the ease with which the position of the landmark allows identification with a unique manoeuvre

- *Visibility* - the ability to see the landmark
- *Uniqueness* - the likelihood of the landmark being mistaken for other objects within the environment

The supplemental analysis revealed that the attributes regarding the expectation of what the landmark will look like (i.e. predictability in appearance and familiarity) generally did not have an influence. It is felt that this occurred because the sample of landmarks that were rated were all familiar objects, and therefore the cognitive demands associated with identifying the object, once seen, are likely to be minimal. Indeed, ratings on the familiarity variable were generally higher than for the other attributes (as shown by Table 7.1).

7.6.5 Methodology Issues

There are several points upon which the study described in this chapter can be criticised:

1) There is no indication as to the reliability in subjects' responses, that is, the extent to which we would expect similar ratings, and thus similar conclusions, with a different sample of drivers or even the same subjects on a different occasion.

2) Variability between subjects' ratings are generally high. Although this may be largely attributed to the natural variations in the quality of landmarks across the environment, possible ambiguities in attribute names, definitions and landmark labels may have affected subjects' responses.

3) There was some evidence (via observation of individual data sets) that a few subjects were giving a 'blanket' rating across all attributes for a given landmark, e.g. deciding that a landmark was 'good' and rating it accordingly for all attributes.

All of these points relate to the inherent nature of the study, that is, subjective ratings. The use of performance-related variables (Chapter 8) provides some objective data regarding the choice of landmarks for route guidance systems.

7.7 Conclusions

- Based on empirical subjective ratings, it is possible to establish a list of potentially useful landmarks for use within a route guidance system in the UK. The following are the top ten scoring landmarks:

1.	Traffic lights	6.	Monument
2.	Pelican crossing	7.	Superstore
3.	Bridge over road	8.	Street name signs
4.	Hump-backed bridge	9.	Railway station
5.	Petrol station	10.	Church

- This list is based on their use within a route guidance system as information for helping drivers in locating manoeuvres. Furthermore, the landmarks listed above are UK specific, and it is quite possible that within other environments these landmarks will be less appropriate or indeed completely inappropriate. This is felt to be particularly the case for Pelican crossings which are, according to the best knowledge of the author, unique to the UK, and those landmarks which are not part of standardised road infrastructures (e.g. Superstore, Church).

- With respect to the landmark selection issue, the conceptual considerations described in section 7.3.2 have enabled the identification of 11 potentially influential attributes of 'good' landmarks. These are listed below, together with basic definitions:

Permanence...............................	The likelihood of the landmark being present
Visibility....................................	Whether the landmark's size/shape means it can be seen clearly in all conditions
Conspicuity..............................	The attention-grabbing nature of the landmark
Predictability in location........	Knowing where to look for the landmark
Openness..................................	The likelihood of the landmark being obscured by other objects, etc.
Familiarity................................	Whether the landmark is well known
Predictability in appearance..	Knowing what the landmark will look like
Uniqueness	Whether the appearance of the landmark is such that it is unlikely to be mistaken for anything else
Degree of separation	The extent to which examples of the landmark are 'far apart'
Usefulness of location	Whether the landmark is located close to navigational decision points
Compactness............................	Whether the size of the landmark allows it to be easily related to a turning

- It is likely that all of these attributes will, under particular conditions, contribute to what constitutes a 'good' landmark for navigation. However, it is also probable that some will be consistently more important than others, that is, they will influence the success or failure of a landmark on a greater number of occasions. In this respect, the results of this subjective rating study provide some indications as to which attributes are most significant. Analysis revealed that, for everyday discrete objects within the driving environment, three underlying factors were of greatest importance, and thus should be considered by designers of map databases: the ease with which the *location* of the landmark allows a navigational manoeuvre (e.g. a turning) to be identified; the *visibility* of the landmark; and the likelihood of the landmark being mistaken for other objects within the environment (*uniqueness*). The permanence of the landmark is a prerequisite factor to consider.

- In general terms, it is felt that the work reported in this chapter serves as a valuable pilot study for a more detailed analysis of the topic (via a systematic research programme). The primary advantage of being able to conduct a systematic series of studies concerning the choice of landmarks for route guidance systems would be that a focused, evolutionary approach could be taken. To date, only single experiments have been conducted investigating the use of landmarks as elements of research projects with more global aims (e.g. Alm et al., 1992; Green et al., 1995). As a consequence, little attempt has been made to address the various complex issues associated with landmark use (some of which have been highlighted by this chapter), e.g. landmarks as classes of objects compared to specific objects, context of information presentation, environmental factors, individual driver differences, the requirements of industry, etc.

Chapter 8: Road-based studies - An assessment of landmarks versus distances

8.1 Introduction

On the basis of results in this thesis and elsewhere (e.g. Alm, 1990; Green et al., 1993a; Bengler et al., 1994), it is clear that there is a strong requirement among drivers for the use of landmarks within route guidance system HMIs. Unfortunately, there has been little consideration of performance-related effects, particularly with respect to the use of a wide range of different landmarks. The need for such work is apparent, given the results of Chapter 5, since in that study subjects extracted a great number of distinct landmark types (29 in all) from the real world environment for the purposes of supporting the navigation task.

A further set of issues relate to the use of distances (e.g. the words "300 metres", or countdown bars) within route guidance system HMIs. Previous chapters have raised concerns regarding the use of distance as a primary means of enabling a driver to locate a manoeuvre. In particular, within Chapter 4 subjects rated distances to be of little use for navigation, and remarked that they did not feel confident in judging distances while driving.

The work reported in this chapter addresses these issues using the data generated by two road-based studies*. Each of the studies was conceived to answer particular human factors design issues concerning route guidance systems, and a summary of their main findings is included for the purposes of providing background knowledge (sections 8.4 and 8.5). In each study, an emphasis was placed on one of two different information types, either landmarks or distance-to-turn, within the Human-Machine-Interface (HMI) of the route guidance systems being tested. For the purposes of this thesis, the focus of this chapter is on a *comparison* of results across the two studies, based on three dependent variables (sections 8.6 and 8.7).

* As noted in Chapter 1 (section 1.10), the original studies were conducted by an MSc Information Technology student (Patel, 1994), and a BSc Ergonomics student (Ekerete, 1994).

8.2 Aim

The aim of the work reported in this chapter was to compare and contrast the relative performance of a route guidance HMI which emphasised landmarks versus one in which a reliance was placed on the use of distance-to-turn information.

8.3 Overall methodology considerations

In order to enable some basic comparisons to be made across the two road-based studies, a number of methodological features were deliberately maintained across them by the PhD author*. The following points indicate these commonalities, and provide an overview of the methodologies of the two studies:-

- Both studies took place on public roads in the same urban driving area - the city of Leicester in the UK. It was arranged that the route used was the same across both studies. This route required 20 navigational decisions at a number of different junction types of differing complexities (e.g. T-junctions, X-roads, turn off roads, roundabouts) and took approximately 20 minutes to drive. A map showing the common route used in these studies is included as Appendix 8A.

- The same instrumented vehicle (Saab 9000i hatchback) was used for both studies.

- The same display type (Monochrome 5.75" LCD), and position (on the dashboard above the central column of instruments) was adopted throughout (see Figure 8.1).

- All of the visual symbols used in the studies were of similar sizes and design (e.g. black on white). The same 'straight on' symbol was used in both studies (see Figure 8.1), to inform the driver to keep going on the current road. This symbol was presented immediately after a turning and up until the final approach to a manoeuvre.

* Differences between the studies did arise (specifically, in experimental designs, subject ages and genders) - their implications are discussed in section 8.7.5.

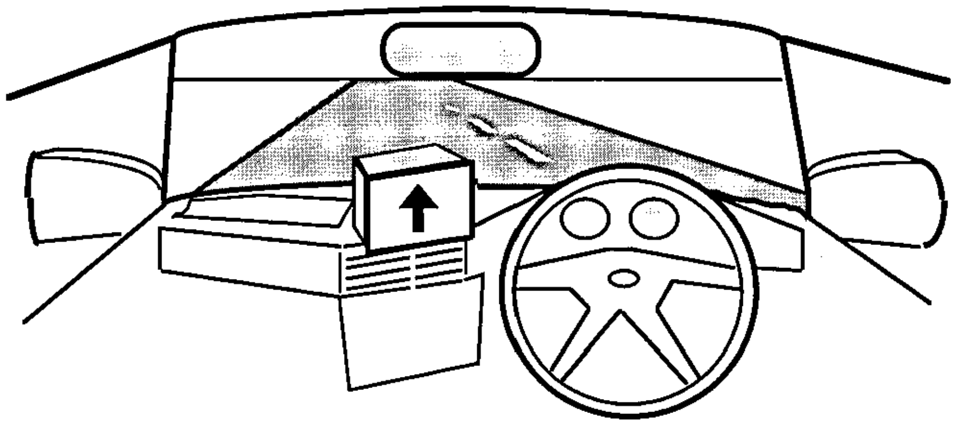


Figure 8.1 - Position of route guidance display used in studies (plus example of 'straight on' symbol)

- The voice messages used were all spoken by the same female voice (digitised speech), preceded by an auditory beep.
- The timing of messages on the approach to manoeuvres was the same across studies, with the first 'approach' message always being given at approximately 200 metres from the junction.
- The experimental training and procedures adopted were similar across the studies. For instance, all subjects were given approximately an hour's familiarisation with the car and the route guidance messages. Furthermore, in all cases the route guidance information was generated by the SuperCard™ program, and manually presented to subjects by the experimenter who sat in the back of the car. An example of the training and procedure for one of the studies is shown in Appendix 8B.
- Three key dependent variables were captured and analysed in the same way across the two studies:
    - *Navigational errors* - defined as occurring when a subject strayed from the given route).
    - *Visual demand of in-vehicle display* - captured via a front facing camera in the instrumented car, and measured post-hoc using video frame analysis. In accordance with the draft ISO standard on visual demand measurement (ISO, 1996), a single glance was

defined as the time from when a subject began to take their eyes off the road until they brought their eyes back to the road ahead view.

* *Perceived workload* - measured in a consistent fashion by a specially tailored version of the NASA-Raw Task Load Index (RTLX) (Fairclough, 1991; Hart & Staveland, 1988, as discussed in Appendix 2B). A copy of the RTLX definitions and rating scale used is given in Appendix 8C.

8.4 Study 1: the use of landmarks

8.4.1 Specific study aims

The primary aim of this study was to establish the relative benefits of presenting landmarks within a route guidance system, as compared to the presentation of basic road layout information. The study also aimed to identify whether any differences arose between two groups of subjects, split by perceived navigational abilities (good or poor).

8.4.2 Method

Subjects

16 subjects took part in this study (8 male, 8 female), with an average age of 38.2 years (SD=14.80, range 23-62). They were currently driving for an average of 5 days per week (SD=2.03, range 1 to 7), and drove an average of 9,300 miles in the previous year (SD=5.74, range 2,000 to 20,000). For this particular study, subjects were chosen on the basis of their perceived navigational skills. Therefore, on a five point scale, half of the subjects considered themselves to be at least "fairly good" at finding their way in unfamiliar surroundings, whereas half considered themselves to be at most "fairly poor".

Experimental conditions/design

There were two experimental conditions in this study: simple visual and auditory instructions; and the same, but with the addition of landmark information at certain manoeuvres along the route, as shown by Table 8.1.

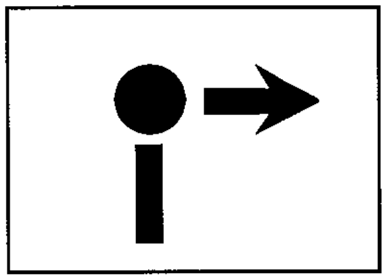
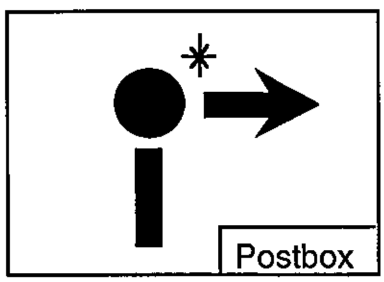
	Visual information	Auditory information
Non-landmark		Turn right
Landmark		Take first turning right at the Post-box

Table 8.1 - Study 1: Examples of visual/auditory information

This study was factorial in design, and subjects were split into two groups: one receiving non-landmark information; and the other receiving landmark information along the same route. Subjects were allocated to each of these conditions such that there was an even split between male/female, good/poor navigators (by self-perception) and under 30/over 40 years of age.

A wide range of different landmark types were referred to in the landmark condition, and were chosen using the results of the study reported in Chapter 5. By design, the majority of the common route used in the studies being discussed here was the same as the route used in the study described in Chapter 5. Consequently, it was possible to make use of specific landmarks that were often referred to by subjects in the video condition of that study. This led to the following landmarks being included in the HMI (Table 8.2):

Landmark types	Number of references
Traffic lights	7
Bridges (over the current road)	2
Shops	1
Phone box	1
Post-box	1
Church	1
Petrol station	1
Bus stop/shelter	1
Park	1

Table 8.2 - Study 1: References to different landmarks

8.4.3 Summary of results

Similar to previous studies concerning landmarks (see Chapter 2), this study found some evidence of subjective benefits of using landmarks in the HMI design for route guidance systems. For instance, there were trends for drivers using the landmark system to feel more confident that they were on the correct route, and were making the right turnings, as compared with those using the basic system ($p=0.12$).

Nevertheless, these differences were not significant, and in objective terms, there was evidence that the addition of landmarks led to reduced driver performance in comparison with the use of basic road layout. For instance, although few navigational errors occurred in this study, the majority (6 of a total of 7) arose in the landmark condition. Further analysis by the present author of the reasons for errors made within this condition revealed that these errors could be attributed to problems associated with the quality of the landmark information within the environment. These specific difficulties are discussed in section 8.7.1.

Many of the differences revealed by this study were between the results of the self-perceived good and poor navigators. The majority of the navigational errors (5 of the 7) were made by the poor navigators. Furthermore, poor navigators made, on average, over twice as many glances towards the display than did good navigators, and rated their overall task workload as significantly higher ($p<0.01$). Poor navigators within the landmark condition also rated the landmarks as being of greater use than did the good navigators ($p<0.05$). This latter result appears to confirm the view expressed in Chapters 2 and 4 concerning the link between perceived navigational abilities and the potential acceptability of a route guidance system that employs landmarks within its HMI.

8.5 Study 2: distance to turn representations

8.5.1 Specific study aims

This study aimed to establish the relative benefits (in terms of driver behaviour, performance and acceptability) of different means of visually presenting distance-to-turn information.

8.5.2 Method

Subjects

12 subjects took part in this study (7 male, 5 female), with an average age of 47.3 years (SD=6.93, range 41-57). They were currently driving for an average of 5 days per week (SD=2.13, range 1 to 7), and drove an average of 11,300 miles in the previous year (SD=5.21, range 5,000 to 25,000). 10 of the 12 subjects considered themselves to be at least "fairly good" at finding their way in unfamiliar surroundings.

Experimental conditions/design

Five conditions were experienced by subjects in this study, all relating to different potential styles of presenting distance countdown information, as shown in Table 8.3.

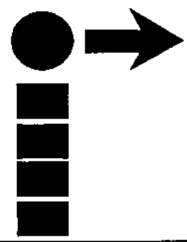
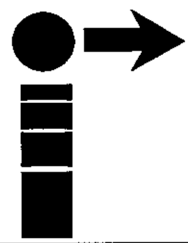
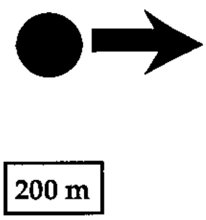
	Integrated distance & arrow	*Split screen* distance & arrow	Auditory information
Equi-distance			
Vari-distance			Turn right in 200 metres
Text			

Table 8.3 - Study 2: Examples of visual/auditory information

This study was repeated measures in design, such that each subject drove a single route using a simulated visual and auditory route guidance system which presented all five of the different types of distance countdown information described above. The auditory information was given to complement the visual information (single instructions on commencing the final approach to a manoeuvre).

Each of the four equi-distance countdown bars 'emptied' at the following distances (in metres) from a manoeuvre: 150; 100; 50; and 0. In contrast, each of the vari-distance bars emptied at the following distances: 100; 50; 25; and 0 metres. The text-based condition followed the same progression as the vari-distance bars. To give an idea of relative distances, an outline of the countdown bars remained after bars had emptied, as shown by the example in Figure 8.2 below:

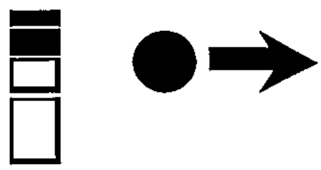


Figure 8.2 - Example of emptying countdown bar

The presentation of the different symbol types at succeeding junctions was randomised so that subjects could not predict what the next symbol type would be, with the proviso that each subject experienced each symbol type on at least four occasions.

8.5.3 *Summary of results*

There were no significant differences between the different means of presenting distance to turn information for navigational errors, visual demand or perceived workload. The greatest number of navigational errors (7 of 13 in total) occurred when subjects were using the text-based messages, highlighting (a) the difficulties experienced by drivers in judging absolute distances (as expressed by drivers in Chapter 4), and (b) the incompatibility between the representation of distance as text (i.e. verbal format) and its use for locating a turning (i.e. a spatial task). These points will be discussed in more detail in section 8.7.2.

With respect to drivers' visual behaviour, there were no apparent differences in the visual demand associated with the varying means of presenting distance-to-turn information, with the range in mean glance duration values equal to 0.09 seconds (lowest mean=0.78 secs; highest mean=0.87 secs). With respect to the subjective data, the factor that most dictated overall preference was whether the distance bars were integrated with the arrow, although the vari-distance symbol types were generally preferred to their equi-distance equivalents.

It was hypothesised prior to this study that the additional perceptual cues present within the vari-distance countdown bars (i.e. relative size changes), and the increased fidelity offered by this style when close to the desired manoeuvre, would lead to objective, performance-related benefits to the drivers (e.g. reduced number of glances), in comparison with the equi-distance bars. There was no evidence for this effect, and in retrospect, it was felt that the two conditions were not sufficiently different from each other to investigate the hypothesis adequately.

8.6 Comparing results across the two studies

8.6.1 Introduction

In this section, some basic comparisons are made between the results obtained in the studies described above, based on three common dependent variables: navigational errors, visual demand, and perceived workload. To enable such comparisons, the following three data analysis decisions were taken:

1) The results obtained for the different 'distance-to-turn' displays (Study 2) were collapsed to provide a single value for a distance-centred HMI across the experimental route. This was felt to be justifiable given the lack of significant differences between conditions in this study with respect to performance-related variables.

2) In the glance data analysis, values were calculated for the 'straight on' displays, as well as the 'approach' displays. As the straight on displays were exactly the same across the two studies, it was expected that similar visual demand figures would be achieved for the landmark system (Study 1) versus the distance-to-turn system (Study 2).

3) The two groups of subjects within the studies were treated as independent groups, and some basic statistical comparisons were made (unpaired t tests). This analysis was intended to provide some indication of the extent of differences, to provide some weight to the points made thereafter.

8.6.2 Navigational errors

Table 8.4 reports the mean number of navigational errors made by subjects (and the associated variability) for the two route guidance HMIs.

	Landmark (n=8)	Distance-to-turn (n=12)
Mean	0.75	1.08
SD	0.707	1.379
Range	0-2	0-4

Table 8.4 - Navigational errors made across the two studies

As can be seen, there were some errors made by subjects using the landmark oriented system (6 errors across 8 subjects), and the greatest number of errors arose for a 'distance-to-turn' emphasised HMI (13 errors across 12 subjects). These differences did not reach significance (p=0.54).

8.6.3 Visual demand

Tables 8.5, 8.6 and 8.7 report the findings across the different studies for three fundamental metrics of drivers' visual behaviour:

- Glance duration - the duration of single glances made towards the route guidance display
- Glance frequency - the number of glances made towards the route guidance display
- Glance allocation - the percentage of time in motion spent glancing towards the route guidance display

As stated in section 8.6.1, a differentiation is made between the results relevant to the 'approach' messages (i.e. from 200 metres prior to a junction until the junction) and those relevant to the 'straight on' messages (i.e. at all other times).

Glance duration

	Landmark (n=8)		**Distance-to-turn (n=12)**	
	Approach	Straight on	Approach	Straight on
Mean	0.66	0.53	0.83	0.69
SD	0.09	0.06	0.12	0.13
Range	0.56-0.82	0.44-0.60	0.68-1.10	0.57-1.05

Table 8.5 - Duration of display glances across the two studies

The duration of glances towards the 'approach' landmark display (mean 0.66 secs) was significantly shorter as compared with the equivalent distance-to turn display (mean 0.83 secs, t(18)=3.365; p<0.005). A similar result was apparent with respect to the straight on displays (p<0.005).

Glance frequency

	Landmark (n=8)		Distance-to-turn (n=12)	
	Approach	Straight on	Approach	Straight on
Mean	1.60	1.20	5.04	1.93
SD	0.88	0.80	1.41	1.16
Range	0.53-2.90	0.36-2.45	3.35-7.60	0.90-4.6

Table 8.6 - Frequency of display glances across the two studies

As shown by Table 8.6, considerably less glances were made on the approach to junctions when subjects were using a landmark emphasised route guidance HMI (mean 1.60) versus a distance-to-turn centred HMI (mean 5.04, $t(18)=6.134$; $p<0.0001$). Although there was a trend for less glances to be made towards the straight on display in the landmark study, as compared with equivalent glances made in the distance study, this difference did not reach significance ($p=0.143$).

Glance allocation

	Landmark (n=8)		Distance-to-turn (n=12)	
	Approach	Straight on	Approach	Straight on
Mean	5.3	3.5	21.5	6.4
SD	3.42	2.58	5.68	3.54
Range	1.6-11.1	1.1-8.1	15.9-33.5	2.0-16.0

Table 8.7 - Glance allocation (%) across the two studies

As can be seen above, a considerably lower percentage of driving time (in motion) was spent glancing towards the route guidance display on the approach to junctions, when the primary information presented was landmarks (mean 21.5%), versus a landmark (mean 5.3%) emphasised HMI: $t(18)=7.227$; $p<0.0001$. As for glance frequency, there was a non-significant trend for less proportion of time in motion to be spent glancing towards the straight on display in the landmark study, as compared with equivalent time spent in the distance study ($p=0.06$).

8.6.4 Perceived Workload

For the NASA-RTLX each subject made a rating on six discrete components of perceived workload (mental demand, mental effort, physical demand, time pressure, distraction and stress levels). The sum of the component values was divided by six to calculate each subject's overall perceived workload score.

The mean of the overall perceived workload scores associated with each condition is shown in Figure 8.3. A value of 0 corresponds to a rating of 'Low' workload, whereas 100 corresponds to 'High' perceived workload. The graph shows that, overall workload was perceived to be higher with the distance-to-turn centred HMI versus the landmark oriented display: $t(18)=2.578$; $p<0.05$.

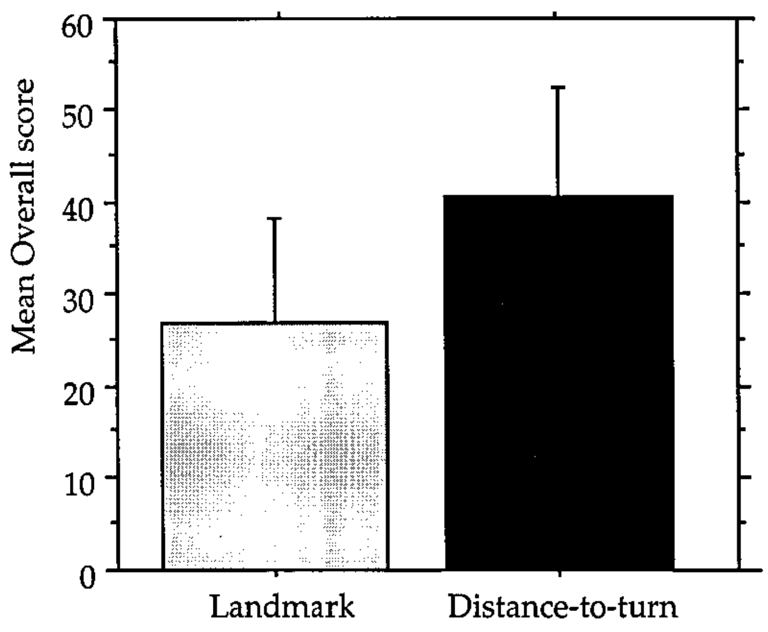


Figure 8.3 - Mean overall workload scores (with standard deviation bars)

Table 8.8 reports the mean ratings made for the different components of workload across the two studies.

	Landmark (n=8)	Distance-to-turn (n=12)
Mental Demand	20.9	46.1
Mental Effort	42.8	51.1
Physical Demand	24.4	27.2
Time Pressure	18.7	34.2
Distraction	35.9	55.4
Stress Levels	18.3	29.6
OVERALL	26.8	40.6

Table 8.8 - Mean scores of each component of the NASA-RTLX across the two studies (plus the mean overall scores)

The table shows that the landmark-emphasised HMI was generally rated lower on all workload dimensions in comparison with the distance-to-turn oriented HMI. This was particularly the case for the following dimensions in which statistical significance was reached: Mental Demand ($t(18)=3.291$; $p<0.005$); Time Pressure ($t(18)=2.090$; $p<0.05$); and Distraction ($t(18)=2.101$; $p<0.05$).

8.7 Overall discussion

On the whole, the comparisons reported in section 8.6 highlight effectively the benefits associated with a route guidance HMI that places a reliance on landmarks as opposed to distance-to-turn information. When landmarks were a central component of the HMI, on average, less than a third as many glances were made towards the route guidance display, as compared with an HMI in which distance (presented either graphically or textually) was used as the primary means of locating a manoeuvre. On the whole, single glance durations and perceived workload were also lower when this type of information was being used.

The following sections (8.7.1 to 8.7.3) discuss the particular results for each of the three dependent variables (navigational errors, visual demand and perceived workload), primarily in relation to the landmark-emphasised HMI. Two further sections (8.7.4 and 8.7.5) will discuss some individual difference results and general methodology issues.

8.7.1 Navigational errors

Some navigational errors resulted when subjects used the landmark information. As stated earlier, the author conducted a more detailed assessment as to the reasons behind such errors, and this revealed that of the six navigational errors made in the 'landmark' condition, all occurred at junctions in which landmarks were present. In four of these, traffic lights were the presented landmarks, and for the other two, a post-box was given in the 'approach' message. With respect to traffic lights, analysis of subjects comments revealed that there was some confusion between two particular sets of traffic lights that were situated close together. The voice message said "take 1st turning right after traffic lights" instructing drivers to turn off the current road immediately after a set of traffic lights at a pedestrian crossing. However, in situations where errors arose, subjects mistook the traffic lights at the pedestrian crossing with those further ahead at a major junction. As a result, they drove on and ignored the fact that the "1st" turning had been recommended. Such confusion appear to confirm the importance of Uniqueness (in location and appearance), reported in Chapter 7 as an attribute of good landmarks.

In the case of post-boxes, both navigational errors arose due to the variance in the visibility of these objects. In both cases, the post-box was hidden by a parked vehicle, such that it could not be seen until the driver was very close to the turning. Again, these difficulties appear to confirm the significance of Visibility (under all circumstances) as an attribute of suitable landmarks. They also illustrate a potential problem with the use of landmarks as primary information within a route guidance HMI, in that drivers may place a greater reliance on such information as compared with other types of information. In this instance, therefore, drivers may have assumed that the post-box was present and visible, and thus continued past the recommended turning believing the landmark to be further along the road.

These idiosyncratic results are important, since they highlight the significance of the reliability in a landmark's quality, and the need for a tool which can aid map database companies in selecting and prioritising appropriate examples of landmarks (as expressed and investigated in Chapter 7).

As a further point, the results can be used to make a hypothesis regarding the effect of landmark reliability on system acceptability. It can be expected that a landmark-emphasised HMI may increase system acceptability in situations where all (or the vast majority) of the included landmarks are of a high quality (e.g. they are present, clearly visible and located close to the intended manoeuvre). However, it seems reasonable to assume that the inclusion of only a few 'poor' landmarks within a route guidance HMI, particularly if they lead to navigational errors and/or high workload, could adversely affect drivers' satisfaction with the system. The importance of different levels of reliability in landmark quality, as contrasted with the reliability of other information types (e.g. distance-to-turn, junction characteristics, road signs) would be a topic worthy of further investigation.

Despite the above points, it is worth noting that several other landmark types (nine in total) were presented to subjects in Study 1. There was no evidence within the results of this study that subjects experienced any difficulties in using these landmarks to support the navigation task. This is an important result, since in previous studies (e.g. Alm et al., 1992; Bengler et al., 1994; Green et al., 1995), relatively few distinct types of landmark were included within the route guidance HMIs (predominately traffic lights and bridges). Study 1 demonstrates that a wide range of landmarks can be incorporated within a system HMI with few negative effects on driver performance.

8.7.2 Visual Demand

The benefits of landmarks

In comparison with the distance-to-turn centred HMI, the landmark-emphasised HMI led to approximately a third as few glances and lower glance durations. Clearly, such results reflect the relative ease by which subjects were able to extract information from the landmark display and use this for the purposes of identifying a turning. Taking a wider perspective, Table 8.9 contrasts the mean glance duration revealed in Study 1 for the landmark-emphasised HMI with the durations found in road-based assessments of other turn-by-turn route guidance systems. Whilst admittedly a speculatory comparison, given differences across studies in the subjects, routes and experimental designs employed, the figures do seem to suggest that the landmark display was associated with relatively low visual demand.

	Mean Duration (secs)	Basic description of turn-by-turn system
Fairclough & Parkes (1990)	1.30	Visual only: Scrolling text display under user control
Ashby et al. (1991)	0.90	LISB/Ali-Scout - Visual and voice: Basic road layout plus distance (text & countdown bar)
Burnett (1992)	0.78	Visual and voice: Basic road layout, plus integral distance countdown bars
Dicks (1994)	0.74	Visual and voice: Detailed road layout, plus street names for half of turnings
Burnett & Joyner (1997)	0.96	Philips CARiN - Visual and voice: Detailed road layout, plus text distance to turn
Burnett & Joyner (1997)	0.99	Motorola - Visual and voice: Basic road layout, plus road names and distance countdown bar
Dingus et al. (1997)	0.87	Travtek - Visual and voice: Basic road layout, plus road names, and distance (text & countdown bar)
Study 1	0.66	Visual and voice: Basic road layout together with landmarks (position and name)

Table 8.9 - Examples of glance durations from road-based assessments of different turn-by-turn HMIs

The 'distance' problem

The visual demand results reported in section 8.6.3 primarily reflect the difficulties experienced by subjects using the distance-to-turn oriented HMI when approaching a manoeuvre. Therefore, they demonstrate in objective, performance-related terms the views expressed by drivers in previous chapters of this thesis. Some attention is given here as to the reasons why drivers experience problems with distances, utilising background literature from the psychology field. It is felt that such a discussion is of significance given the emphasis that many route guidance systems place on such information.

In contrast with landmarks, for the most part, distances are not directly perceived from the environment (some road signs do contain distances). Instead, the ability to use such information has to be learnt, particularly in relation to distance systems, e.g. yards or metres. It is clear from the results of this study, plus those within the background literature (e.g. Montello, 1991; Wiest & Bell, 1985), that satisfactory learning is not undertaken by people primarily for two reasons:

1) There are generally few instances, within everyday tasks, where people need to estimate distances of this range. This is reflected in the fact that

distances, particularly absolute distances, are rarely provided in peoples' navigational directions (Ward et al., 1986; Davis, 1989).

2) The accuracy of people's judgements are rarely appraised, that is, little feedback is given (H. Palmen - Personal communication, February, 1998). This point suggests that it would be worthwhile (from an eventual efficiency point of view) for a route guidance system to provide some feedback regarding navigational errors, although there is a danger that this level of information could compromise overall system acceptability.

These points raise the question as to whether, following extensive practise with a system, driver performance with the 'distance-to-turn' centred HMI could be equitable with that of the landmark oriented system. An evolutionary perspective indicates that the answer to this question is likely to be negative. For instance, the use of exact units for representing distance is a relatively recently developed concept (Montello, 1991). Furthermore, in the driving situation, distance judgements will have to be made at speeds in which the human race has had, in evolutionary terms, little time to adapt (Gibson, 1996).

The discussion so far is primarily of relevance to the estimation of absolute distances (in this case, 200 metres). The HMIs used as part of the distance-oriented system also utilised changing distance values (either a countdown bar or text) to indicate the location of the next manoeuvre. Figure 8.4 attempts to describe, in simplistic terms, how the use of such varying information resulted in a number of glances being made towards the distance-to-turn centred HMI on the approach to a manoeuvre. The bold line on the graph shows a distance/time relationship which assumes a steady reduction in speed on the approach to a desired turning (i.e. the manoeuvre recommended by the system).

Following the initial presentation of the 'approach' route guidance message (in this study at 200 metres from the junction), the driver will glance towards the route guidance display and/or listen to the auditory message given by the system. Using this, together with an impression of current speed and likely deceleration, s(he) will form an estimate as to the times or distances remaining prior to the potential manoeuvre. These are shown by the outer dotted lines. The initial degree of error in these times/distances (as perceived by the subjects) is indicated by the arrows marked (a), which can also be said to represent the driver's uncertainty in their estimates.

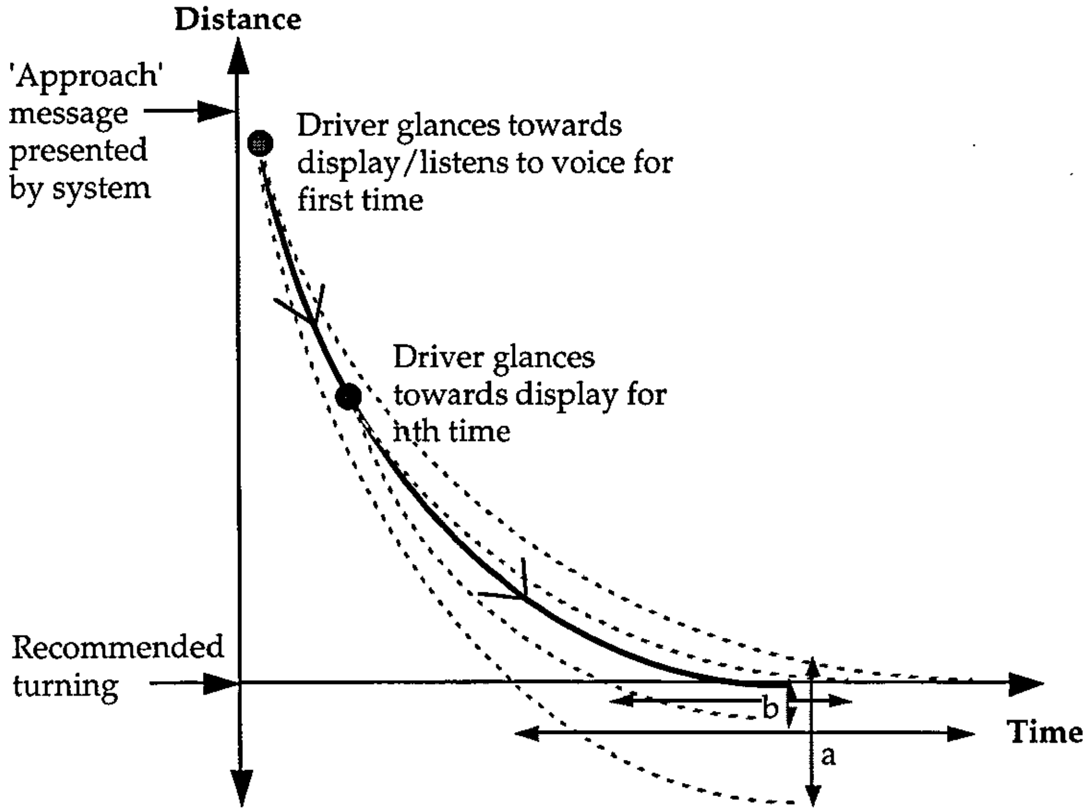


Figure 8.4 - Changes in the error/uncertainty of drivers' distance estimations on the approach to a recommended turning

With further glances towards the route guidance display, the new distance 'value', together with an indication of the rate of change in time/distance (based on previous samples), will be used to refine the estimations. A hypothetical nth glance is shown using the inner dotted lines and the arrows marked (b) which demonstrate how the uncertainty in driver's time/distance estimates will reduce with continuing glances towards the route guidance display.

In situations where there is more than one turning close to the desired junction, it can be easily seen from Figure 8.4 how a reliance on distance-to-turn as a primary means of locating a manoeuvre will lead to increased glances towards the route guidance HMI. The uncertainty in a driver's estimates of time/distance will force them to continue to extract new distances from the system until the perceived uncertainty associated with an estimate is at an acceptable level, that is, until the driver is sure which is the correct turn to make. As a result, glances will continue to be made throughout the approach to such manoeuvres.

Numerous glances towards an in-vehicle display when approaching a junction are considered to be extremely undesirable. In these circumstances, the demands of the driving task are generally high (slowing down, lane decisions, increased need for awareness of other road users, etc.), and a significant time with 'eyes off road' (in this study, an average of 21.5% of approach time) will have negative implications for overall driving safety.

'Straight on' glances

It was interesting to compare the visual demand results associated with the 'straight on' symbols across the two studies. For instance, in both of the studies, a number of glances were made to 'straight on' symbols. To a large extent, such glances can be considered to be 'anticipatory' in nature, that is, the outcome of subjects waiting for new information to appear on the display. This provides increased evidence for a need for pre-information to reduce uncertainty and unnecessary glances towards the visual display.

The visual demand associated with the straight on symbols in the landmark study (Study 1) was generally lower, as compared with that obtained in the distance study (Study 2). This is perhaps surprising given that the straight on displays were exactly the same across the two studies. Nevertheless, it is felt that such a result can be largely attributed to a reduced need among the drivers in the landmark study for confirmation that a correct turning had been made. In effect, it can be argued that the landmarks themselves provided the confirmation, on approach to the turning. In contrast, with the distance-to-turn oriented HMI, it is likely that the abstract nature of this information, together with the demands encountered on the approach to manoeuvres were reflected in a greater requirement for confirming information.

However, it must be noted that this result could also be taken to reflect an increased propensity to look at the route guidance display among the subjects used in Study 2, that is, an increased willingness to take ones eyes off the road, perhaps due to novelty effects.

8.7.3 *Perceived workload*

According to the NASA-RTLX scale, drivers perceived their workload to be higher for the distance-to-turn centred HMI, as compared with the landmark-emphasised HMI. In terms of specific dimensions, ratings were significantly higher for mental demands, time pressure and distraction, largely reflecting the problems experienced in using distances, as discussed in 8.7.2.

With respect to the performance of the landmark-emphasised HMI, observation of the values obtained for the various components of workload (see Table 8.8) revealed some interesting insights into the use of landmarks versus distances. Of most interest were the findings that drivers rated their mental demands when using landmarks to be much lower, as compared with use of distances (means: 20.9 versus 46.1), whereas mental effort scores were generally similar and high (means: 42.8 versus 51.1).

With respect to the low mental demands attained in the landmark condition, it is felt that this result reflects the naturalness of using such prominent objects, particularly within turn-by-turn descriptions of routes. As discussed in Chapter 6, landmarks constitute fundamental components of cognitive maps, and also play an important part in the environmental learning process (Evans et al., 1984, Kaplan, 1976, Lynch, 1960). As a result, landmarks are commonly used in everyday navigation tasks, such as direction giving. In contrast, distances (particularly absolute distances) are poorly represented in individual's cognitive maps, and thus are rarely included in people's directions.

Mental effort concerns the concentration required during the course of the journey (see Appendix 8C for a full description of the NASA-RTLX factors). For landmarks, it is felt that searching for such information does require a degree of concentration. This will be the case particularly for landmarks which are not integral parts of the road infrastructure, such that their location relative to a manoeuvre or junction is inconsistent and hence less predictable, for example, churches, parks and post-boxes.

These mental effort results raise an interesting issue regarding the use of landmarks within route guidance systems. Clearly, the use of a landmark within a route guidance system will be associated with 'outside-vehicle' visual demands (searching, identifying and relating the landmark to a turning). Accordingly, we can ask ourselves whether such demands are more significant, in terms of their effect on driver behaviour and performance, than equivalent 'in-vehicle' demands?

The results of this study would suggest that the answer to this question is negative, since subjects using the landmark-emphasised HMI gave relatively low ratings for the Distraction dimension of the NASA-RTLX, as compared with ratings for the distance-to-turn HMI (means: 35.9 versus 55.4). The definitions for this scale pointed out that distraction could be caused by events both inside and outside the vehicle. Nevertheless, it is possible that the in-vehicle display was a more obvious source of distraction to the subjects, and was more salient in their ratings, as compared with any sources of distraction within the outside-vehicle environment. Consequently, it is felt that such an issue would best be addressed in the controlled simulator environment utilising an Eye-mark camera to detect where exactly a driver looks (both inside and outside the vehicle) when using landmarks for navigation.

8.7.4 Individual differences

With respect to drivers' performance when using the landmark-emphasised HMI, the most apparent individual differences were due to the factor considered in the original study, that of self perceived navigational ability. Clearly, the results of Study 1 (as described in section 8.4.3) suggest a link between self perception of navigational ability and objective performance when using a route guidance system. Interestingly, the poor navigators rated the landmarks to be of greater use, yet it was these individuals who primarily experienced difficulties in using such information. This paradox suggests that the choice of landmarks is absolutely critical for those who consider their navigational abilities to be poor.

Observation of the measures of dispersion (standard deviation and range) shows that there was generally greater variability in the visual demand results associated with the distance-to-turn centred HMI, as opposed to the landmark oriented display. A similar result was evident for the navigational errors variable. In other words, it is clear that some people experienced greater problems in using this form of HMI than did others. This result is consistent with the background literature which has found that there is considerable variability in people's abilities to estimate distances (Boff & Lincoln, 1988).

As discussed in Chapter 4, there have been studies which have found that males make greater use of distances in navigation (Ward et al., 1986). This would suggest that males might perform better when using the distance-to-turn centred HMI than females. Indeed, there was some evidence for this effect, since in Study 2 males generally made less glances towards the route guidance display on the approach to manoeuvres (mean 4.6) than did females (mean 5.8). However, according to an unpaired t test, this did not reach significance (p=0.16), and there were no apparent differences for navigational errors or perceived workload.

8.7.5 Methodology issues

The central difficulty associated with the exercise reported in this chapter is that the two studies differ in both experimental design and choice of subjects. The following points highlight some particular differences which may have had a confounding effect on the comparative findings discussed so far.

In Study 2, subjects were randomly presented at each manoeuvre with a particular form of 'distance-centred' HMI. Therefore, it seems reasonable to expect that, despite pre-experimental training, there would be a degree of 're-familiarisation' with each approach message, thus resulting in more glances being made towards the route guidance display. However, it must be noted that such an effect would also be present (albeit to a lesser extent) in Study 1 where landmarks were only offered at certain junctions.

With respect to subject differences, it is evident that Study 1 (landmarks) included a greater proportion of younger drivers and drivers with lower perceived navigational abilities, as compared with Study 2 (distances). Concerning possible effects of age differences, one might argue that the performance of subjects within Study 1 was higher than it would have been if subjects of an age similar to those within Study 2 were recruited. However, this postulation neglects the facts that (a) in the distance study, subjects were aged 40-60 and not strictly speaking 'older drivers', and (b) in the original analysis for Study 1, there was no evidence to suggest any differences between age groups.

The fact that there were more subjects in the landmark study who perceived their navigational abilities to be poor would suggest that the performance results obtained for subjects in the landmark condition were generally *lower* than they might have been if the proportion of self-confessed poor/good navigators was similar across studies. This prediction is strengthened by the consistent findings in Study 1 that performance was lower for the 'poor' navigators (see section 8.4.3).

8.8 Conclusions

- In addition to the subjective benefits reported in previous work regarding landmarks (e.g. Alm et al., 1992; Green et al., 1993a), it appears that the inclusion of landmarks within route guidance HMIs can lead to objective performance-related benefits for drivers. The landmark-emphasised HMI led to relatively few glances being made towards the display (on average 1.6 on the approach to a turning), and workload was perceived to be lower (mean 26.8 on a 1-100 scale, where 1=low and 100=high), in comparison with the figures attained for a distance-to-turn oriented HMI (mean number of glances: 5.0; mean workload 40.6). Furthermore, in contrast with previous assessments of route guidance HMIs, the durations of glances towards the landmark display were low (mean 0.66 secs).

- Nevertheless, navigational errors did arise in the landmark condition. Difficulties with traffic lights (a uniqueness problem) and post-boxes (a visibility problem) led to such mistakes. The idiosyncratic nature of these errors, and the possibility that drivers may place a greater reliance on landmarks within a route guidance HMI, emphasises the need for a human factors tool that ensures that only 'good' landmarks are included in future map databases. Related to this, there appears to be a fundamental need to assess the implications of different levels of landmark quality on driver performance and system acceptability.

- With respect to subjects' ratings on the individual workload scales, comparisons revealed that the perceived mental demands associated with using the landmark-emphasised HMI were relatively low (on average, less than a half those attained for the distance system). However, mental effort ratings were similar across the two conditions. Two factors are believed to have led to these results: the naturalness associated with referring to landmarks within turn-by-turn directions; and the concentration required when scanning the road ahead for landmarks. Of relevance to this second point, there is a research need to establish the 'outside-vehicle' visual demands associated with the use of landmarks within route guidance systems.

- Distance-to-turn information is not considered to be a desirable means of informing the driver as to the location of a manoeuvre. Performance was relatively poor, for instance, on average, three times as many display glances were made on the final approach to a junction when drivers were using the distance-to-turn centred HMI, as compared with the landmark-emphasised HMI. Background research within the psychology field provides some explanations as to why people experience difficulties judging distances, in contrast with using landmarks.

Chapter 9: An overview of the thesis results - Towards a 'first stage' design tool

9.1 Introduction

The previous chapters of this thesis have described and discussed a series of empirical studies and two literature reviews. This chapter aims to synthesise the research findings presented by the thesis and the background literature. Several important outputs emerge as a result of this synthesis:

- A simplistic breakdown of the key stages in the driver's navigation task. Within this breakdown, the goals of drivers (e.g. to correctly identify which way to travel at the next manoeuvre) are extracted from research findings, and related to the general timescales in which they are of importance (e.g. on the final approach to a turning).

- A list of the full range (termed a 'pool') of information elements of potential use in supporting the drivers' navigation task. To achieve this, enhancements are made to the categorisation scheme proposed in Chapter 5, based on a consideration of the spatial and temporal means by which information is used to support the navigation task. A limited validation of the pool is provided via a review of the functionality of a range of current route guidance systems.

- A first pass specification of the information elements that a route guidance system should provide to help drivers find their way in unfamiliar surroundings. A summary matrix is included outlining those information elements which are considered 'potentially suitable' for supporting a stage of the navigation task. As such, this matrix forms the initial framework for a design tool to aid in the design of context-dependent route guidance systems, capable of adaptation to the prevailing navigational situation.

- A discussion of the role of other aspects of 'context' in the choice of information for a route guidance system, specifically environment and user context, and how these might be defined in future work.

9.2 Breakdown of the navigation task

As outlined in Chapter 2, to date there has been no satisfactory analysis of the driver's navigation task. Figure 9.1 is an attempt to remedy this situation utilising the results described in this thesis. As can be seen from the diagram, navigation is viewed as a continuous task, in which support is required across a number of different stages, for example, prior to setting off, on the approach to a manoeuvre, in the period immediately following a manoeuvre, or across the whole timeframe of the navigation task.

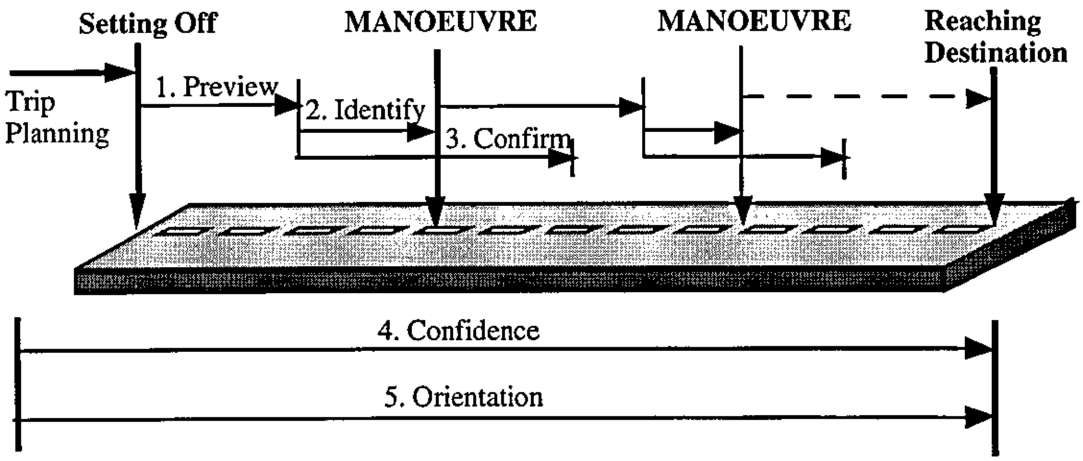


Figure 9.1 - The stages of the driver's navigation task

The primary reasoning behind offering such a temporal description of the navigation task is that it enables the goals of drivers to be assigned to each stage, which in turn can enable drivers' information requirements to be specified. As discussed in Chapter 2, a central disadvantage of current models of route guidance system use is that they cannot be readily related to the design of system HMIs.

Table 9.1 summarises the driver goals and approximate timescales associated with the different stages of the navigation task - a detailed discussion of the evidence for each of the stages then follows. The focus of this thesis is the provision of information to support route following. Therefore, trip planning, although critical to overall system usability (Dingus, Hulse, Krage, Szczublewski & Berry, 1991), will not be considered here.

Stage	Timescales	Drivers' goals
1. Preview	After a manoeuvre up until final approach to next manoeuvre	• To obtain perception of time/distance remaining until next manoeuvre • To obtain a mental picture of the next manoeuvre • To gain preparatory knowledge regarding future positioning on road
2. Identify	On the final approach to a manoeuvre	• To pinpoint within the road environment the location of the next manoeuvre • To identify which direction to travel at the manoeuvre • To exercise suitable speed control on the final approach • To establish correct on-road positioning on the final approach
3. Confirm	On the final approach to a manoeuvre and immediately following	• To establish whether the correct manoeuvre has been identified • To establish whether a navigational error has been made
4. Confidence	Throughout the pre-drive/en-route period	• To gain reassurance that the correct route is being followed • To gain reassurance that the system is functioning correctly
5. Orientation	Throughout the pre-drive/en-route period	• To gain an awareness of current location in relation to general surroundings/ destination

Table 9.1 - the timescales and goals of drivers for different stages of the navigation task

1. Preview - There are three fundamental aspects to this stage:

- *Immediacy* - The tendency of drivers to check route guidance visual displays for new information, particularly in the period immediately following a manoeuvre, (noted in the two road-based studies reported in Chapter 8) indicates a requirement for notification of the immediacy of a manoeuvre. Similar findings have also been noted by Green et al. (1995) and Zaidel & Noy (1994). A lack of preview information of this kind will encourage poor driving behaviour (e.g. slowing down before, and as turnings are passed, misleading use of indicators), as noted in Chapters 3 and 5.

- *Overview* - It was clear from the interviews in Chapter 3 that drivers perceived a need for some form of overview of the oncoming manoeuvre prior to the final approach. It is felt that the benefits of such support relate primarily to the role of expectations. By informing the driver of appropriate details of the next manoeuvre, a mental model of its appearance can be formulated. This will be utilised on the final approach to the junction, to enable faster decision making.

- *Lateral positioning* - The study reported in Chapter 5 revealed that drivers perceived a strong need for lane information to enable correct lateral positioning prior to the final approach to a manoeuvre. It is clearly important that drivers are well prepared for lane changes (Green et al., 1995; Ross et al., 1995), and providing this level of information in advance allows the driver to utilise guidance within existing road signs.

2. Identify - There can be no doubt that the critical stage of the navigation task in terms of driver performance occurs on the final approach to a manoeuvre. It is only during this time that the precise location of the manoeuvre and required direction of travel can be observed by the driver. The efficiency with which a route guidance system supports this aspect of the navigation task has been the focal point for most research, leading to recommendations for the design of the HMI (e.g. Fastenmeier et al., 1994; Zaidel & Noy, 1997; Srinivasan & Jovanis, 1997). This is to be commended, since it is during this stage that the demands of the driving task are high (slowing down, looking out for other road users, etc.), and therefore, it is essential that optimal route guidance information is presented.

Two further aspects of navigation are covered by this stage, that of exact lateral and longitudinal control. Navigation information can ensure that the driver chooses the appropriate lane on the approach to a manoeuvre, and can also help the driver to adjust vehicle speed in an appropriate manner, by, for example, identifying key junction attributes (roundabout versus slip road, sharp turn versus bear, etc.)

3. Confirm - Throughout this thesis, several results have indicated a need for information to enable more than just correct identification of manoeuvres en-route (see Chapters 4, 5 and 8 in particular). A general requirement was for information that confirmed that the correct manoeuvre was either about to be taken or had already been taken. Obata et al. (1993) noted similar results in their road-based study - see section 2.3.2.

A second aspect of the Confirm stage can be identified - navigational error feedback. Some of the drivers in Chapter 3's road study described how they noted environmental information (e.g. landmarks, street names) situated past their turning in case a mistake was made. Streeter et al. (1985) have commented on the importance of such information within good navigational directions.

Evidently, both aspects of this stage are primarily related to drivers' wants and preferences, rather than their objective needs (as is the case for the previous two stages). Therefore, the extent to which a system supports the Confirm stage will have a strong bearing on its overall acceptability.

4. Confidence - A further stage with implications for system acceptability is 'Confidence'. It was evident in Chapter 5 that much of the information extracted from the 'real world' (i.e. the video) was for the purposes of providing reassurance that the driver was on the correct route (e.g. 'straight on' references, key landmarks along a route, etc.). In addition, this stage accounts for the importance of drivers perceiving correct system functioning prior to and during a journey - this has been discussed by Alm (1990).

5. Orientation - The studies described in this thesis have not specifically addressed the requirement of drivers for orientation information (although some comments can be made on the basis of results in Chapters 3 and 5). The concept of orientation has been defined by Arthur and Passini (1992), as follows:

" orientation ... concerns a person's ability to perceive an overview of a given environment and recognise where he or she is at any given time within it" (pp.224-225)

Therefore, orientation concerns drivers' needs for general spatial awareness and knowledge of current location. As discussed in section 2.6.3, there have been some studies which have concluded that drivers require an overview of a route (HUSAT, 1989; Mark, 1989). However, the results of Obata et al. (1993) - see section 2.3.2 - suggest that drivers perceive little need for orientation information during a journey. The importance of orientation information, and whether any individual differences are present, needs to be investigated in dedicated research studies.

All of these topics are particularly relevant to the development of map type displays, since much of the information required for orientation is best presented in this format (Mashimo et al., 1993).

9.3 Development of a 'pool' of route guidance information

In Chapter 5, subjects viewed either a simulated 'real-world' representation of a route or paper maps, and extracted the information they considered to be of use for navigation. The results formed the basis for a detailed categorisation scheme for information elements (see Table 5.2). This list can also be seen as a 'pool' of information which could potentially be presented by a route guidance system to support the driver's navigation task.

A disadvantage of the list in Table 5.2 is that it does not consider the overall spatial and temporal means by which information will be used for supporting the navigation task. For instance: ego-centred directions may refer to the next manoeuvre or to a destination point; path geometry may apply to the current route or to other roads. In other words, there is a need to recognise that, at any given instant on a journey, navigation information may be referenced to a number of different points in space or time, either:

1) **along the desired route**. A distinction can be made between references according to the driver's:

- current location (e.g. present road (name, class, etc.) and area (name, characteristics)
- immediate future (e.g. next street name, distance to next turning, oncoming junction type or angle, landmarks)
- non-immediate future situations (e.g. the name of the street after next, impending junction types, future en-route landmarks)
- final destination (e.g. the direction or distance to this point)

2) or: **off the route**, i.e. the surrounding environment (e.g. direction or distance to key landmarks or points of interest in the vicinity, the layout of neighbouring roads or junctions).

This limitation can be largely attributed to the nature of the study in which the categorisation scheme was generated (Chapter 5) which encouraged subjects to focus on their route-following needs. Nevertheless, utilising the above points, it is possible to propose a wider, more useful range of information elements. Figure 9.2 demonstrates, using the example of road/street names, how the original list of information elements is transformed.

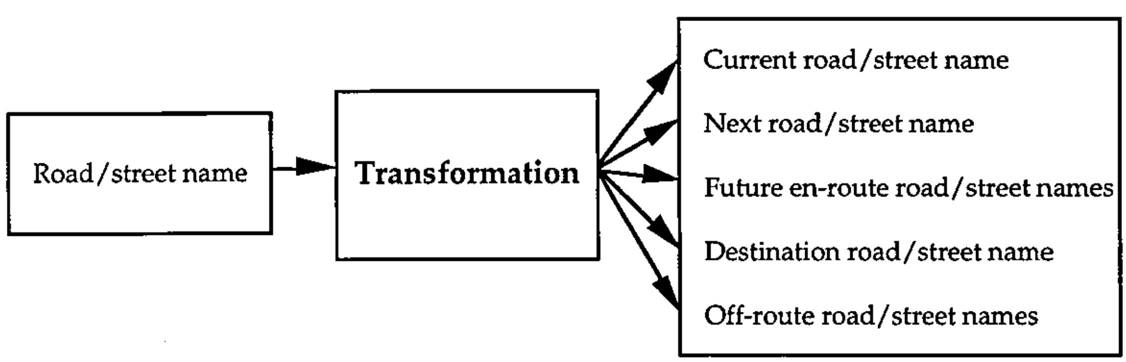


Figure 9.2 - Example of the transformation of information elements

The transformation exercise led to a final pool of 74 navigation information elements. Table 9.2 summarises what are considered by the author to be the most important information elements, and provides some examples. The full list can be seen in Appendix 9A.

Category	Information elements	Examples
Direction	Ego-centred direction along current road	"Keep going straight on"
	Ego-centred direction of next turning	"Turn left", a "right" arrow
	Ego-centred direction to destination	An arrow pointing towards the destination
	Ego-centred direction to surrounding roads/junctions/landmarks, etc.	An arrow pointing towards the nearest petrol station
	Local-referenced direction of next turning	"Turn left towards the post-box"
	World-referenced current direction	"You are heading South"
	World-referenced direction of next turning	"Turn, heading North"
	World-referenced direction of destination	"The destination is North-West"
Distance	Absolute distance to next turning	"turn left in 300m"
	Absolute distance to destination	"The destination is 2 km away"
	Absolute distance to surrounding roads/ junctions/ landmarks, etc.	"The nearest restaurant is 3 miles away"
	Relative distance to next turning - referenced to previous turning	A countdown bar that reduces between previous/next turning
	Relative distance to next turning - referenced to approaching point	A countdown bar that reduces on approach to a turning
	Relative distance to destination - referenced to start point	"You are half way there"
	Cost-based distance to next turning	"Turn right soon", "left now"
	Cost-based distance to destination	"Your destination is far away"
Path (Road)	The class of the current road	"You are on the A47"
	The class of the next road	"Turn onto the main road"
	The class of surrounding roads	Colour coding of the class of different off-route roads
	Geometry of the current road	"follow road around bend"
	Geometry of the next road	A bend shown in the next road
	Geometry of surrounding roads	Bends/dips on surrounding rds
	Lanes to take on current road	"move into right hand lane"
	Road rules on current road	"Follow one way road"
	Prior turns on current road before next decision point	"take 2nd left turning"
Node (Junction)	Angle of next junction	"Take sharp left", "bear right"
	Angles of surrounding junctions	Angles shown within map view
	Type of next junction	"Turn left at T-junction"
	Types of surrounding junctions	Types shown within map view
Landmarks	Names of landmarks close to next junction	"turn right at post-box"
	Names of surrounding landmarks	"monuments" within map view
	Descriptors for landmarks	"the white house", "BP garage"
	Locators for landmarks	" shop on corner", "church on left"
	Reference prepositions for landmarks	"right before shop", "left at lights"
Road Signs	Surrounding place names	"Derby" shown on map view
	Number of current road	"The current road is A417"
	Number of next road	"Turn onto M1"
	Number of surrounding roads	"A6", "B212" on a map view
	Name of current road/street	"Keep on Park Drive"
	Name of next road/street	"Turn onto Gilbert Road"
	Name of surrounding roads/streets	"Wolsey Way" on map view
	Number of next junction	"Exit at junction 7"

Table 9.2 - 'Pool' of potentially useful navigational information elements

As a means of providing some validation of the pool, a review of the information present within a range of current and recent route guidance system HMIs was conducted. Whilst it is admitted that such an approach is limited, given that the chosen systems may have inherent weaknesses in their HMIs, it was felt that the exercise would give some practical support for the pool.

The HMIs of ten systems were examined, five of which have been used directly by the author. Descriptions within research papers or marketing publications were the source of information for the other systems. Table 9.3 shows sample screens and voice messages for *four* of these systems, and describes the information present within the primary HMIs (i.e. those designed to be the principal means of enabling a driver to locate a manoeuvre), utilising the list in Table 9.2. The equivalent table for the remaining six systems can be seen in Appendix 9B.

On the whole, the validation exercise provides a high level of confidence in the inclusiveness of the information pool, since the vast majority of information elements within the HMIs were adequately covered. Only one real difficulty was encountered in using this scheme for defining the information content of route guidance system HMIs. This concerned whether a map/symbolic representation of a junction actually revealed its type (e.g. T-junction, roundabout, etc.). For systems such as no.1 and no.2 in Table 9.3, it was clear that insufficient detail was available to indicate the junction type. However, the situation is less certain with more diagrammatic representations, e.g. systems no.3 and no.4, where more specific junction information is provided (in these cases, the correct physical layout and some knowledge of priorities is given).

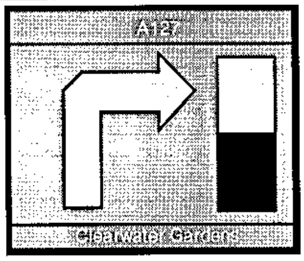
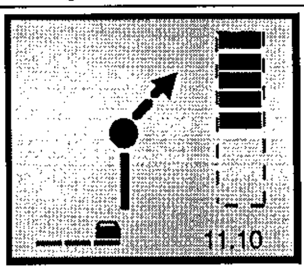
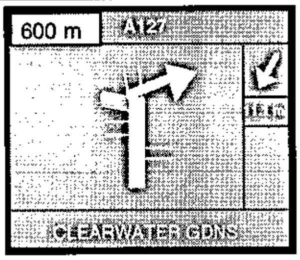
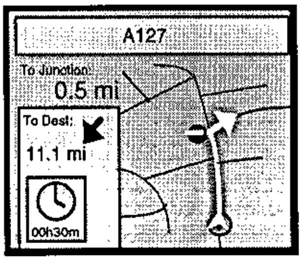
System/ Reference	Sample HMIs - visual and voice	Information elements
1. Bosch Berlin™ - Bosch (1998, January)	 "Right turn in 600 m"	Ego-centred direction of next turning Absolute distance to next turning Relative distance to next turning Name of current road/street Name of next road number
2. Autoguide/ LISB/ Ali-Scout™ - Ashby et al., (1991); Eby & Nostyniuk (1997)	 "Prepare to turn right"	Ego-centred direction of next turning Absolute distance to direction Relative distance to next turning Lanes to take on current road Angle of next junction
3. Philips CARiN ™ CC93 - Hook (1997, March)	 "Take 2nd turning right"	Ego-centred direction of next turning Absolute distance to next turning Absolute distance to destination Path geometry - current road Rules on surrounding roads Turns on current road prior to next decision point Angle of next junction Angles of surrounding junctions Type of next junction Name of current road/street Number of next road
4. Alpine NVE-N055VP™ - Crawford (1997)	 "Right turn 600m ahead"	Ego-centred direction of next turning Ego-centred direction to destination Absolute distance to next turning Absolute distance to destination Relative distance to next turning Relative distance between surrounding roads/junctions Cost-based distance to destination Path geometry - current/next/ surrounding roads Rules on surrounding roads Turns on current road prior to next decision point Angle of next junction Angles of surrounding junctions Number of next road

Table 9.3 - Information present within a range of route guidance systems

This problem reflects the fact that the pool was originally generated in a study (Chapter 5) in which the majority of information was verbal in nature (written notes). Therefore, the information element 'junction type' was based on verbal labels (e.g. T-junction, X-roads, Roundabout, etc.) which implicitly inform the driver of a number of characteristics relating to a junction, e.g. the likely spatial layout, traffic priorities, and road widths.

This does not mean that the pool is invalid, rather that some rules need to be established to decide the level of detail at which a diagrammatic representation of a junction provides an equivalent level of information to a verbal 'junction type' label. A simple survey of drivers would seem to be an appropriate means of achieving this.

9.4 The suitability of navigation information

The central question of interest in this thesis has been: what information should be provided to drivers during a journey to support them in the navigation task? Importantly, the pool of information elements in Table 9.2, together with the definition of the navigation task described earlier, form a basic *framework* in which this question can be answered in detail. As such, the framework forms the basis for a future design tool for exploring options for information content within route guidance HMIs.

For each of the stages of the navigation task, the *suitability* of information elements (taken from the pool of potential information) for presentation by a route guidance system can be evaluated. In general terms, 'suitability' can be said to refer to how well the information allows drivers to achieve their navigational goals. Therefore, it is analogous to the concept of 'task fit' within the general HCI literature (Sutcliffe, 1988; Booth, 1989), and includes a consideration of drivers' expectations, abilities and limitations and likely preferences and wants.

The following sections (9.4.1 to 9.4.5) make some preliminary statements regarding the suitability of key information elements for supporting different stages of the navigation task. Knowledge gained within this thesis, plus that present in the literature, and, in certain cases the expert opinion of the author, is used as source material.

9.4.1 *Preview*

The provision of information to support the preview stage of the navigation task is equivalent to the use of pre-information (see section 2.3.6 within the literature review). As can be seen in Chapter 2, there has been little consideration of the design of the pre-information HMI, and the studies included within this thesis also have not focused on the development of such advance warning messages. However, it is possible to make some recommendations, as follows:

Immediacy
The results of Chapter 5 suggest that drivers perceive distances in non-precise terms, such as "near", or "far", and would therefore benefit from the use of informal cost-based distances (e.g. "keep on this road *for some time*") to indicate the immediacy of a manoeuvre. The background literature (Chapter 6) confirms such a viewpoint, since peoples' mental representations of the environment rarely contain exact distances (Downs & Stea, 1977; McDonald & Pellegrino, 1993).

However, the comments provided by some subjects in Chapter 4 suggest that explicit use of vague terms as a feature of a route guidance HMI will be treated (at least by particular drivers) as an indication of a lack of quality on the part of the system, rather than a more 'natural' system. It is possible that this individual difference is linked to gender, since all of the subjects who made this comment were male, and in other parts of Chapter 4's questionnaire male subjects were found to exhibit a greater preference for the use of distances in navigational directions (also found in the study by Ward et al., 1986).

As a further point, it is felt that presenting the required junction number on appropriate roads (i.e. motorways and some main A roads) will implicitly indicate how far away a manoeuvre is, given knowledge of current location. In Chapter 4, junction numbers were considered to be extremely useful for navigation when travelling on motorways and dual carriageways.

Overview
Given the results reported in Chapters 3 and 5, it is argued that the most suitable way of providing drivers with a mental picture of the next

manoeuvre is to inform them of its type (e.g. X-roads, roundabout, T-junction, turn off road, etc.). For basic manoeuvres such as these, drivers will have a well defined schemata regarding the appearance of the junction, which can thus be easily processed, remembered and then recalled for supporting the Identify stage of the navigation task. Not all junctions will fit into neat categories though, and it is likely that, for more spatially complex manoeuvres, information such as the class of the next road or the angle of the turning will be needed.

Lateral positioning

The most apparent means of preparing drivers for a future lane choice decision is to inform them of the lane to take (e.g. the voice message, "Prepare to move into right hand lane"). However, although no such opinion has been expressed in the literature, it is questionable as to whether such explicit information is the most appropriate means of preparing drivers, as it may unnecessarily leave them 'on edge' (that is, in anticipation of a manoeuvre).

Consequently, *implicit* information such as the direction of the next manoeuvre (left/right/straight on) may be the most appropriate method for helping a driver prepare for movement in multiple lane choice situations. In addition, the provision of certain information present within road signs (e.g. junction and road numbers) will also be important, since road signs (at least within the UK) are designed to provide preparatory information to enable timely lane positioning (Jeffrey, 1981). This is particularly the case for major roads within urban areas, where the choice of a correct lane is likely to be critical (as suggested by the results of Chapter 5).

9.4.2 *Identify*

As stated earlier, researchers have much to say on drivers' information requirements during the 'Identify' stage of the navigation task. As will be seen below, though, there are still some unresolved questions.

Pinpointing location of manoeuvre

Given the difficulties that drivers experience in making distance judgements (reported by many subjects in Chapters 4, and confirmed, objectively, via the comparisons described in Chapter 8), the use of absolute distances, such as

300 metres, is not considered to be a suitable means of enabling a driver to pinpoint a manoeuvre.

The evidence regarding the use of relative distance information is generally negative, suggesting that these too should not be designed to be the primary means for aiding drivers in locating a manoeuvre. Relative distance information is usually displayed as countdown bars or a moving vehicle arrow. In the second of the studies reported in Chapter 8, although countdown bars were preferred to the text (absolute distances) information, when compared to the use of proximate landmarks, driver performance was relatively poor. A 'reduction in uncertainty' perspective, as described in section 8.7.2, can be used to explain why such HMIs can be distracting.

In the human factors literature, both negative (Srinivasan et al., 1994; Green et al., 1995) and positive (Winkler & Nowicki, 1997; Carpenter et al., 1991) comments have been made with respect to the use of countdown bars, as discussed in section 2.4.2, suggesting that results are dependent on the means by which the information was presented.

The results of Chapters 3, 4 and 5 suggest that certain 'road' information will help drivers in particular situations to identify a manoeuvre uniquely, for instance, the class of the next road (e.g. motorway, A road, residential), road geometry (e.g. bends in the road close to a turning) and no-entry roads (observable on signs). As a related point, it has been noted that drivers can be "pulled" towards large junctions, expecting to take a major rather than minor turning (Green et al., 1995). Explicitly presenting the classes of roads surrounding the intended junction will help to overcome this effect.

Providing information regarding the number of turns prior to a manoeuvre allows drivers to adopt a counting strategy (e.g. "3rd left"), an approach which was perceived to be beneficial in the first of Srinivasan et al's simulator studies (1994). In Chapter 5 of this thesis, many drivers extracted this information from both the video and the map, particularly in situations when turning off the current road, and when multiple turn off roads were close to one other. However, in Chapter 4, drivers reported a number of concerns in using this information, e.g. the demands associated with remembering how many turns are left or have been passed, and the exact conditions in which the presentation of prior turns is suitable needs to be established.

Junction angle information is required for the identification of the oncoming manoeuvre, since drivers will expect any displayed angle information to correspond to their view of a junction (e.g. a right angled display arrow will lead the driver to expect a right-angled junction). This has been expressed by Verwey and Janssen (1988), as noted in Chapter 2 of this thesis.

Junction type was referred to extensively by subjects in both the map and video conditions in the study described in Chapter 5. It was rated to be of particular importance in urban areas in the questionnaire study of Chapter 4, and for more complex manoeuvres in Dicks (1994). This type of information is well-learnt (Ross et al., 1995), and thus enables easy mapping between displayed information and the driver's view of a manoeuvre, ultimately improving the efficiency of the decision making process.

The use of landmarks (e.g. traffic lights, post-boxes, public houses) within a route guidance HMI has been a particular focus of this thesis, and the results of Chapters 4 and 5 in particular suggest that, for supporting the Identify stage of navigation within urban areas, this information has considerable potential. As summarised in Chapter 6, the 'naturalness' of such prominent objects can lead to efficient navigation decision making. Nevertheless, it is fundamental that appropriate landmarks are utilised, and by comparing the results of Chapters 4, 5 and 7 with those reported in the literature review (Table 2.3 in Chapter 2), it is evident that there are some generically good classes of landmarks. The minimum set would appear to be traffic lights, bridges and petrol stations. Such landmarks could be utilised by route guidance systems in a number of varying navigational situations across different environments. It is felt that such landmarks possess high visual distinctiveness (as described in Chapter 6), i.e. their characteristics, which set them apart from other features of the environment, are purely sensory and objective in nature, e.g. high contrast, distinctive shape, bright surfaces. This explains why they can be of use in this performance-oriented stage of the navigation task.

The results of Chapter 4 indicate that drivers perceive particular information within appropriate road signs to be of use for identifying the correct manoeuvre. Information such as road or junction numbers, and place names are considered to be important when travelling on motorways and dual carriageways. Nevertheless, as is apparent from the problems encountered in Chapter 3, it is critical that such information is actually present on the road sign. In the UK, it can be difficult to predict what place names are likely to be on a road sign (as explained by Jeffrey, 1981), since strategies used on all non-trunk roads vary across county borders.

Direction to take

There can be no doubt that the use of ego-centred directions (e.g. left/right/ straight on) is the most appropriate means of indicating which way to turn at the next manoeuvre (Chapter 5, and Alm, 1990, Obata et al., 1993, Green et al., 1995). The use of such a reference system is consistent with drivers' perceptions of routes (Alm, 1990), is a generally well-learnt skill (Corballis & Beale, 1976), and thus will be associated with strong expectations. A locally-referenced direction to take (e.g. "turn left towards the school") will be of some use in particular situations, i.e. when an appropriate landmark is present.

Little requirement for world-referenced directions (e.g. "head in a northerly direction") emerged in this thesis, most likely due to (a) the irregular nature of UK road network, and (b) the limited inclusion of such information on road signs in this country. This does not mean the use of such information should be discounted, since there is likely to be a greater need for world-referenced directions in environments which support its use, e.g. where there is a grid-like road network in which road signs commonly include compass directions.

Longitudinal control

This thesis has not specifically addressed drivers' requirements for information that will aid in longitudinal control on the approach to a manoeuvre. As noted in section 9.2, it is felt that knowledge of junction type (e.g. T-junction versus slip road) and angle (sharp versus bear) will aid in appropriate speed control.

Lateral control

Information regarding which lane to take on the current road is clearly critical to the 'Identify' stage of navigation. In Chapter 5, this type of information was extracted by many subjects from the video as a means of communicating lateral control, particularly in complex inner-city circumstances. Such results suggest that knowledge of the number of lanes on any given road and the ideal lane(s) to take for a particular manoeuvre must be held by map databases. However, it is not recommended that explicit lane recommendations (e.g. the voice message, "move into the right hand lane") should be given for all manoeuvres in which a lane choice is required. As noted for the Preview stage, implicit information (e.g. "turn right at the next junction"), together with appropriate road signs and markings can aid in lane choice decisions. There is a fundamental need to establish in what exact situations (defined by the number of potential lanes, junction characteristics, etc.) explicit information should be given versus implicit information.

9.4.3 *Confirm*

That correct manoeuvre has been taken

The results of this thesis (in particular, Chapters 4 and 8), and the supporting literature (Streeter & Vitello, 1986), suggest that some drivers (e.g. those who lack confidence in their navigational abilities) will perceive a strong need for reassuring information.

Although not stated in the literature, it is felt that distance-based information may be of use for this stage of the navigation task. For instance, once committed to a turning, information such as a low distance-to-turn figure (e.g. 20 metres) or an 'emptied' countdown bar may confirm that a correct manoeuvre is being taken. Certain road information that can be present immediately after a turning may also aid in manoeuvre confirmation, for example, a sharp bend in the next road, or some indication as to the class of this road (e.g. a main or a minor road).

Particular landmarks such as railway stations, monuments, churches, etc. have great potential as information to support the Confirm stage of the navigation task. Such landmarks possess characteristics which are more subjective in nature (termed functional and inferred distinctiveness in the background literature - Chapter 6) than do the 'Identifying' landmarks discussed in the previous section. However, the variability in the intrinsic quality of such information (highlighted by the difficulties encountered with specific landmarks in Chapter 8) necessitates exact criteria for choosing specific examples within the environment. This selection issue will be discussed in more detail in section 9.5.1 of this chapter.

The results of Chapter 3, Chapter 4 and Dicks (1994) suggest that road/street names can act as confirmatory information. Nevertheless, in a similar fashion to the use of landmarks, quality is highly variable, and signs may not be present, difficult to locate and/or read from a distance (Chapters 3 and 4, and also noted by Schraggen, 1990 in the Netherlands, and Davis, 1989 in the US).

On major roads certain road signs in the UK are given just after a turning, and are specifically designed to act as confirmatory information (The Department of Transport, 1995b). Generally, such signs contain the number of the current road, and key place names.

That navigational error has been made

Feedback relating to navigational errors seems to be an aspect of drivers' requirements which has attracted few comments in the literature. The general human factors literature states that feedback is essential if drivers are to learn from their mistakes (Sanders & McCormick, 1993). However, the peculiarities associated with the driving situation suggest that this might not be as desirable a strategy as might be initially expected. Explicit notification of an error (e.g. a voice message "You have missed your turning") could ensure that a driver was 100% certain that a mistake had been made, and would thus aid learning. However, as noted in Chapter 8 such messages might compromise overall system acceptability. In this respect, implicit notification (e.g. a voice message "Re-calculating route") might be better, since drivers are left to *assume* an error, rather than being *told* of their mistake. However, such a solution may not aid learning, and could still be considered by drivers to be annoying. In summary, there is clearly some need for human factors work on this topic.

9.4.4 Confidence

In route following

The provision of information to support the Confirm stage of navigation will also aid in driver confidence in route following, since a manoeuvre is evidently just one part of the whole route. However, other information may also be of use between successive manoeuvres, particularly when distances between turnings are large. In Chapter 5, in the video condition, subjects made a number of 'straight on' references (e.g. "carry on going past the church"). It is felt that information of this kind implicitly notifies the driver that s/he is on the correct route. For reasons similar to those discussed in the previous section, landmarks will provide this level of confidence, although it is believed that other unique and highly visible features of the environment, e.g. road geometry (such as bends in the road), and road signs will aid in route following confidence.

In system

Although the issue of confidence in the workings of the system has not been addressed in this thesis, it is felt that the use of precise, absolute distances to the next turning can aid in this aspect of navigation. For example, a figure of 0 metres when the driver is at a manoeuvre will give feedback to the driver that the system is functioning correctly. The provision of absolute distances on more than one occasion as the driver approaches a manoeuvre (e.g. counting down on a screen), will also encourage confidence in the system.

9.4.5 Orientation

It is difficult to make firm points regarding the choice of orientation information, given the lack of empirical data within the literature, as discussed earlier. The central problem is that studies (including Chapter 5 of this thesis) have focused on drivers' descriptions of routes, at the tactical level of the driving task, rather then overall strategic requirements. However, some limited knowledge was gained in this thesis, specifically via the content of drivers' pre-trip plans in Chapter 3, and the individual difference results within Chapter 4.

For instance, the results of Chapter 3 suggest that a wide range of different information may be of potential use for orientation purposes. From observation of the list in section 3.4.1, it appears that orienting information is either referenced to the destination (e.g. ego-centred direction/distance to destination, name of destination), or refers to the surrounding environment (e.g. the basic spatial arrangement of off-route roads). Unfortunately, it is not possible to make any more specific comments without a dedicated study.

It is interesting to note that several of the current route guidance systems provide information such as ego-centred direction/distance to destination and current compass heading (see Table 9.3 and Appendix 9B), presumably for basic orientation purposes. However, there appears to be little human factors comment regarding the usefulness (perceived or otherwise) of such information. Green et al. (1995) note that several drivers in their road-based studies (Green et al., 1993b; & 1993c) did not notice the compass directions, although such information was perceived to be of use following the trials.

Both the results reported in Chapter 4 and Lawton (1994) indicate that the requirement for orientation information will be greater for some people than for others, for example males compared to females. It is also probable that the requirement to be 'oriented' will vary for the same driver across different journeys, for example, when on a leisure journey compared to a business journey, although no such comment has been made in the literature.

9.4.6 Summary

Table 9.4 is an attempt to summarise the above discussion. A tick mark (✔) is shown if it is considered that a particular information element is *potentially suitable* for supporting a stage of the navigation task. The word 'potentially' is included to reflect the role of both environment and user context in determining whether navigation information is suitable or not - this issue will be discussed in more detail in section 9.5.

Where a question mark (?) is given alongside any of the ratings, then this is intended to indicate that insufficient human factors data exist, and an expert opinion has been offered by the author. The importance of the use of expert opinion in cases where scientific knowledge is lacking has been pointed out by several researchers (Miltenburg & Verwey, 1997; Meister, 1987).

Information elements	Preview	Identify	Confirm	Confidence	Orientation
Ego-centred direction along current road				✔	
Ego-centred direction of next turning	✔?	✔			
Ego-centred direction to destination					✔?
Ego-centred direction to surrounding roads/junctions/landmarks, etc.					✔?
Local-referenced direction of next turning		✔			
World-referenced current direction				✔?	✔?
World-referenced direction of next turning		✔?			✔?
World-referenced direction of destination					✔?
Absolute distance to next turning	✔		✔?	✔?	
Absolute distance to destination					✔?
Absolute distance to surrounding roads/ junctions/ landmarks, etc.					✔?
Relative distance to next turning - referenced to previous turning			✔?	✔?	
Relative distance to next turning - referenced to approaching point			✔?	✔?	
Relative distance between origin and destination					✔?
Cost-based distance to next turning	✔				
Cost-based distance to destination					✔?
The class of the current road				✔	
The class of the next road	✔	✔	✔?	✔?	
The class of surrounding roads					✔?
Geometry of the current road		✔		✔	
Geometry of the next road	✔	✔	✔?	✔?	
Geometry of surrounding roads					✔?
Lanes to take on current road		✔			
Road rules on current road		✔			
Prior turns on current road before next decision point		✔		✔	
Angle of next junction	✔	✔			
Angles of surrounding junctions					✔?
Type of next junction	✔	✔			
Types of surrounding junctions					✔?
Names of landmarks close to next junction		✔	✔	✔	
Names of surrounding landmarks					✔?
Descriptors for landmarks		✔	✔	✔	
Locators for landmarks		✔	✔	✔	
Reference prepositions for landmarks		✔			
Surrounding place names		✔	✔	✔	✔?
Number of current road				✔	
Number of next road	✔?	✔	✔	✔	
Number of surrounding roads					✔?
Name of current road/street				✔	
Name of next road/street			✔	✔	
Name of surrounding roads/streets					✔?
Number of next junction	✔	✔			

Table 9.4 - Matrix of 'potentially suitable' information elements for different stages of the navigation task

9.5 The role of 'context' in the choice of suitable information

A fundamental argument within this thesis, made primarily on the basis of results in Chapters 4 and 5, is for the future development of 'context-dependent' route guidance systems, capable of adaptation to the navigational situation that the driver is currently encountering. In Figure 9.3, three dimensions to context are highlighted, relating to tasks, environments and users. Knowledge (on the part of the route guidance system) of the tasks being supported, the environment that is being travelled through and characteristics of the user will determine, at a given point in time, which information elements are ideally suitable for presentation by a context-dependent system.

One aspect of context is clearly the stage of the drivers' navigation task, and a pragmatic definition of this was used in section 9.4 to describe the information elements that are 'potentially suitable' for presentation by a route guidance system. In this section, some thought is given to the other components of context that are apparent from the results of the thesis, namely that relating to environments and users.

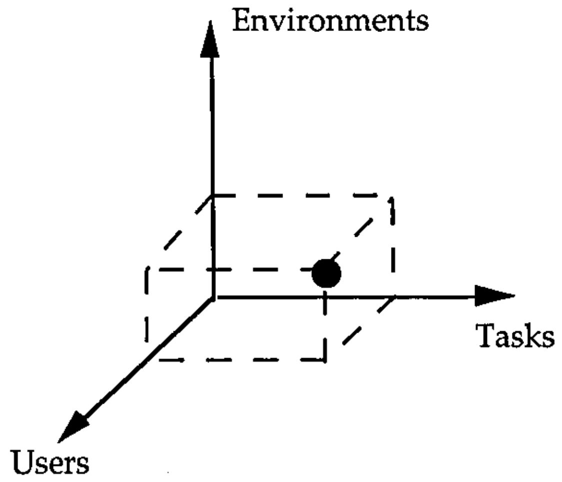


Figure 9.3 - Dimensions of 'context' relevant to the choice of suitable route guidance information

9.5.1 Environment context

This form of context relates to the characteristics of the environment in which navigation decisions are made, for instance, the type of road, the availability of road signs, the visibility of a junction, the location of landmarks. An understanding is required as to what constitutes an 'environment', and Figure 9.4 shows some basic concepts using three examples.

For each of the examples in Figure 9.4, an ever increasing degree of environment context can be said to have been attained. Evidently, such rising levels of environment context necessitate increasing system knowledge of pertinent characteristics of the environment.

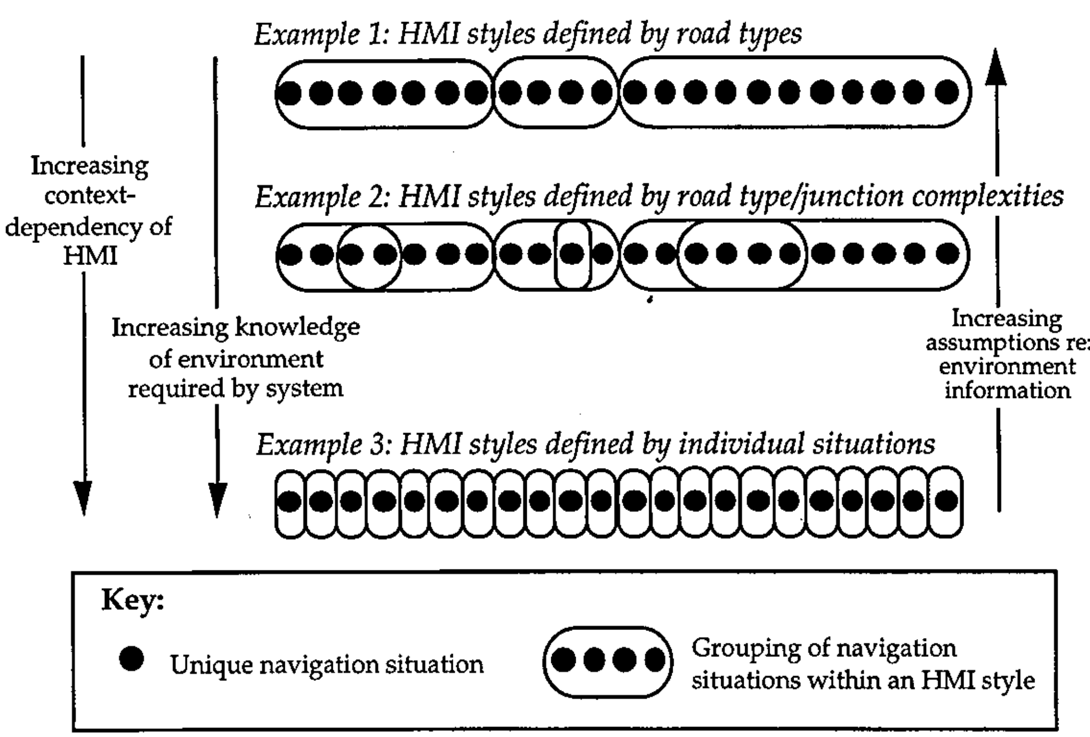


Figure 9.4 - Concepts for environment context

The environment contains a multitude of unique navigation situations for the driver, and these are shown by the dots in Figure 9.4. *Example 1* illustrates a simple means of considering environment context, whereby many of the situations are grouped together within a small number of different route guidance HMI styles (where styles refer to distinct combinations of information within the HMI). In the case of Example 1, a potential grouping mechanism might be road type (e.g. urban roads versus rural roads versus motorways), and, in this respect, the questionnaire survey described in Chapter 4 and Burns (1997a) are of interest. Both surveys revealed, not surprisingly, that drivers prefer road sign-based information on motorways and dual carriageways, and information such as landmarks, road/street names and junction layouts on urban roads.

Such an approach does have practical advantages, since, based on knowledge of road classes, it is a relatively easy task for a route guidance system to alter the information content within an HMI. For example, many route guidance systems do make some differentiation between manoeuvres on motorways compared to other roads, generally emphasising road sign information on motorways and junction layout on urban roads. Unfortunately though, this view of environment context is rather limited, for two main reasons:

1) Only limited environment characteristics are considered. Any statements regarding the suitability of information must be based on many assumptions regarding the kinds of information that might be available to help drivers, and the likely quality of that information. However, it is evident that, particularly in urban situations, (as shown by Chapter 5), the availability and quality of navigation information varies from manoeuvre to manoeuvre. Environment context will also vary over time, as pertinent characteristics of information change (e.g. hidden road signs in the snow, new junctions on a road, changed restaurant name).

2) By focusing on transportation-related terms, particularly UK-based ones such as motorways, dual carriageways, etc., one essentially limits the applicability of results across diverse environments. It is evident that a number of regional differences do exist (Green et al., 1995; Hamahata & Liaw, 1995), for example, in address systems, the structure of the road system, and the means of providing formal navigation signposting.

Example 2 in Figure 9.4 illustrates a more developed approach, in which the information content within a route guidance HMI accounts for situations where the provision of context-dependent information is important. In this respect, relevant situations would be those which are inherently complex in navigation terms, e.g. large, multi-exit roundabouts, close manoeuvres, junctions with no logical type, etc. In Dicks, 1994 (see Chapter 2 - section 2.3.6), subjects using a simple HMI made several navigation errors at more complex junctions, and these were largely overcome when increased road layout information was present. Similar findings have been noted by Alm et al. (1992). To achieve such a level of context-dependency, a definition is required as to what constitutes a 'complex' manoeuvre, so that a system could store this knowledge and adapt the HMI accordingly.

The ultimate means of considering environment context would be on a situation-by-situation basis (*Example* 3). For this level of context, the individual characteristics of potentially suitable information within a given navigation situation must be known, for example, the visibility of nearby landmarks, the precise information contained within road signs, the angle of the turning, the presence of prominent dips in the road, etc.

Clearly, concerns regarding the number of different display formats and layouts that might be required for this level of environment context-dependency can be expressed. Future research should address whether drivers are able to cope with varying combinations of information within a visual and auditory route guidance system.

In addition, this view of environment context is much more difficult to achieve in practical terms than the limited view of context-dependency dictated by road or junction types (as in Examples 1 and 2). In particular, the level to which this can be attained is a function of the way in which data are initially gathered and then updated for map databases. Two specific requirements are required for this level of context-dependency:

1) 'As is' map data, whereby information in the map database reflects exactly what is present within the road environment. Database providers are well aware of the need for frequent updates of their maps, and some technological means of achieving this are discussed in the literature. These can be broken down into those which (a) deal with distribution issues (e.g. the use of kiosks at car dealerships for providing map databases - Gupta and Angerman (1996), or centralised storage of maps which are transmitted via wireless communications - Hakula, Vehviläinen and Ojala (1996)), or (b) aim to improve the up-dating process (e.g. by providing a Help Desk for users to report corrections - Temes (1996)).

2) Some knowledge of the quality of environment information (in relation to the navigation task). Database providers have general quality criteria, such as the extent to which they are complete, correct, up-to-date and accurate (Bastiaansen, 1997). Being 'Complete' would appear to be most relevant to navigation, since it refers to "everything which is necessary in the outside world for good route guidance and navigation" (Bastiaansen, 1997). In this respect, the emphasis is on basic, critical data (e.g. road priorities, one-way streets, turn restrictions), rather than user-centred attributes of information (e.g. visibility, predictability in appearance, etc.).

Ground level data gathering would appear to be the ideal opportunity for considering the suitability of information within the environment for navigation purposes. Unfortunately, visits to locations are extremely labour intensive, and are generally only considered as a last resort if other strategies (e.g. use of aerial photographs, existing maps, phone calls) for data gathering are not successful (Roser & Noonan, 1996; Van Duren & Lydon, 1997). Nevertheless, visits do happen and in Van Duren and Lydon's paper, it is reported that in the compilation of a Point of Interest (POI) database for Rome, due to "inconsistencies in the source materials", over half of the POIs had to be verified (i.e. their existence and location confirmed) via a field visit.

The natural question which follows from this discussion is: how important is it that route guidance systems achieve a situation-by-situation level of environment context-dependency? In answering this question, it is felt that information which is highly variable in terms of its quality in relation to the navigation task requires the greatest consideration at a situation-specific level. As a case in point, many landmark types can vary considerably in whether, for example, they are visible, well located, or even present. As a result, high-level assumptions regarding their suitability will inevitably lead to numerous situations where their presentation by a route guidance system would be inappropriate.

Chapter 7's study made some progress in this direction, since it focused on the characteristics of landmarks within the environment that influence the efficiency of drivers' information processing. In doing so, it was possible to obtain a preliminary definition of the environment context in which particular familiar landmarks (e.g. traffic lights, petrol stations, bridges) are suitable for supporting the Identify stage of the navigation task. This context requires landmarks to be (in order of importance) well located, highly visible, and unique (in appearance and frequency of occurrence). Future work should build on this study in order to develop a tool for use in choosing specific suitable landmarks from the environment.

Other information types will be associated with less variability, and as a result, may not require consideration at a situation-specific level of detail. For instance, formal road signs (e.g. those containing road numbers, place names, compass directions) are generally associated with rules regarding their visual design, location, and the information contained within them. In the UK, this is particularly the case for signs on motorways and trunk roads. Although such rules may not always be apparent to drivers (as evident in Chapter 3's road study), the inclusion of such knowledge within a route guidance system could be envisaged.

9.5.2 User context

Pertinent characteristics of the driver will affect the choice of suitable information for supporting the navigation task, and thus form what is termed 'user context'. Unfortunately, it has not been possible to conduct dedicated individual difference studies within this thesis, and so little progress can be claimed in relation to the status of research as described in Chapter 2's literature review. Some potential differences in relation to driver age and gender are discussed in Chapters 4, 8 and in section 9.4 above.

In a recent paper of interest to the issue of user context, Sargeant (1996) notes the considerable variety in markets for map database products, and discusses the potential for producing personalised maps containing information relevant to an individual. In this paper, it is the varying requirements for knowledge of POIs that is of interest. For example, recommended hotels and restaurants, main tourist attractions, museums etc. may be perceived to be important for leisure travellers, whereas for parents travelling within their local area, information regarding libraries, schools, parks, popular clubs etc. may be salient.

Nevertheless, the principle remains for information relevant to navigation, since drivers may wish their map database to contain information enabling them to navigate using preferred categories of information, e.g. public houses, traffic lights, junction layouts, exact distances. This raises the issue as to whether people can judge what information is best for them - in this respect, evidence from the HCI field suggests that people are generally poor in selecting the most appropriate choice when preferences are made available (Sutcliffe, 1988). Hence, it may be preferable to develop a simple means of classifying people, perhaps on the basis of a questionnaire administered at point of sale. Such a questionnaire could be used in a wider sense to determine optimum HMI styles, whereby information content is just one aspect, together with consideration of information presentation issues.

Chapter 10: Thesis conclusions and further work

"Long is the way, and hard, that out of hell leads up to light"
John Milton (1674/1957, p.242)

10.1 Contribution to knowledge

Many of the individual chapters of this thesis include their own concluding sections, and these study-specific conclusions will not be repeated here. In particular, Chapter 9 (section 9.4) details many design recommendations that have arisen as a result of the work described in the thesis. The purpose of this section is to declare the overall and most important contributions of this thesis to research knowledge. Four particular contributions are apparent:

1) It is argued that route guidance systems should *not* employ *generic* approaches with respect to the inclusion of navigation information in the Human-Machine Interface (HMI). Typically, information such as road/street names, distance to next turn, and basic road/junction layout, is often used generically across different navigational situations (see Table 9.3 and Appendix 9B). Whereas previous research has led to some negative comments being made regarding the use of road/street names (e.g. Davis, 1989; Schraggen, 1990), and basic road/junction layouts (e.g. Alm et al., 1992; Dicks, 1994), the dangers of promoting a reliance on distances via the choice of HMI information have not been recognised. In this respect, it is felt that the results of the questionnaire survey (Chapter 4) and the road-based assessments (Chapter 8) are of particular significance. In short, it is considered that distance-based information is incompatible with the requirements of the drivers' navigation task, for instance, for the purposes of identifying specific decision points. As a result, an emphasis on this information within a route guidance system HMI can lead to considerable demands on the driver (in terms of attention and workload), and potentially poor acceptability of a system.

2) Conversely, it is argued that route guidance system designers should strive for increased *context-dependency* in the choice of information within the HMI. In other words, the information provided should be a function of the

particular navigational situation or context that the driver is encountering. Although others have argued for the use of a limited number of landmarks as a means of providing greater context (Alm, 1990; Green et al., 1995; Bengler et al., 1994), the point is taken further here, and the results of Chapters 5 and 8 are noteworthy. In Chapter 5, it was apparent that drivers considered an extensive range of different information (particularly landmark types) to be of use in supporting the navigation task. Furthermore, when this information was combined, it was done on a junction-by-junction basis, rather than generically across a route. Chapter 8 provides evidence that a route guidance HMI can include a wide range of different landmarks (e.g. traffic lights, churches, parks, shops) with positive effects on driving and navigating performance, in relation to other methods.

3) A list (termed a 'pool') of potentially suitable information elements has been generated. According to the author's knowledge, this pool is the most detailed and practical breakdown of navigation information that exists, and, as such, is an important achievement of the thesis. Using the pool should, in principle, enable researchers to compare results of future information content studies. Furthermore, it can be used to classify the information content of any particular route guidance HMI, and thus may form part of a standardised design or evaluation tool.

4) Central to the realisation of the first two points above is the development of a working definition of 'context'. On the basis of the results of this thesis, an initial *framework* is proposed, whereby context is defined in terms of the drivers' navigation task, attributes of the driving environment and characteristics of the user. In this thesis, the greatest attention has been given to describing the navigating task, and six distinct stages have been outlined, in which driver goals are specified, together with the general timescales in which goals have to be achieved. Whilst it is admitted that this is a basic view of navigation, in contrast with previous work, the definition has considerable practical value - in effect, it provides the means by which one can consider drivers' requirements for route guidance information in detail. In this respect, it has been possible to produce a matrix in which potentially suitable information elements for presentation by a route guidance system are specified.

The need for a detailed, yet pragmatic, understanding of environmental and user context remains. The unique study concerning the choice of landmarks detailed in Chapter 7, provides the platform upon which to achieve this level of knowledge in relation to environment context. Describing the attributes of specific landmarks in user terms such as visibility, usefulness of location, familiarity etc., and then considering their relative importance, has led to an approach which is environment-independent. In the author's opinion, it is the principle that is of significance here, since, with further development, this user-centred technique may form part of a process for aiding in the selection of optimal information for inclusion within future map databases.

10.2 Future work issues

A number of future work issues have arisen and been noted during the course of this thesis, and these are not repeated here. Instead, this section follows on from the above statements, and addresses what needs to be done in order to achieve greater context-dependency in the design of route guidance system HMIs. In this respect, the matrix of 'potentially suitable' information elements (Table 9.4) provides the initial basis for a 'first stage' design tool. To take the concept of a design tool forward, several steps can be conceived, as summarised in the following points.

1) It is apparent from the question marks in Table 9.4 and the discussion in section 9.4 that there are many gaps to fill in human factors knowledge regarding the suitability of different information elements for supporting aspects of the driver's navigation task. This is particularly the case for the Confirm, Confidence and Orientation stages of navigation.

2) A detailed understanding of environment and user context is required to establish in which situations potentially suitable information is actually suitable. These two aspects of context will effectively form additional dimensions to the matrix within Table 9.4. With respect to environment context, it is critical that a means of identifying suitable information for a given navigational situation is developed which is both user-centred and of practical use. In this latter regard, there is a fundamental need to establish the current and future working practices of map database companies. For user context, a greater understanding is required as to how information requirements vary as a function of different user characteristics, and how these might be captured in a practical fashion (e.g. via a questionnaire).

3) Some consideration is required on the subject of how different information might be prioritised, and how the trade-offs associated with different choices can be communicated to system designers. A common complaint of designers towards human factors design advice is that it is often too 'idealised', and should instead state the pros and cons of different human factors solutions, particularly the implications of *not* implementing a recommendation (May, Burnett, Ross & Ashby, 1998; Rouse & Boff, 1998).

As a final point, it must be noted that the selection of suitable navigation information is just one aspect of the design of the HMI for route guidance systems. Although not relevant to the concept of context-dependent route guidance systems as defined in this thesis, it is anticipated that designers will expect a design tool to provide comprehensive advice. Consequently, a series of design tools would need to be developed (of which the 'information suitability' analysis would form the first part), e.g. how much information is required, allocation to modality and format, scheduling of information, display considerations, etc. Together, these (accounting for design constraints such as display size, the content of the map database, etc.) would help to formulate some design options for iterative usability testing and validation. Evidently, fundamental work is required to establish exactly how these individual decision tools would be employed (utilising the results of empirical research discussed in Chapter 2 and Appendix 2A).

10.3 Trends in route guidance HMI - "The future"

Human factors research regarding route guidance systems is by no means a static topic. There are many technological developments being discussed in the literature that have implications for the HMI issues of the future, and to give a final, wider perspective on the thesis, these are summarised briefly below. In particular, their relevance to the realisation of greater context-dependency within route guidance systems is noted, where applicable. The ultimate realisation of these technological advances will be dictated by costs, the nature and strength of markets, and any future standards or legislation/ regulations.

10.3.1 Integration

It is widely predicted that the realisation of a two-way communications link between the vehicle and the infrastructure/other vehicles will lead to an explosion in the application of information technology within vehicles (Zhao, 1997; Whelan, 1995; Catling, 1994). As a result, in addition to the route guidance function, a wealth of new services will be available for use by drivers, for example, real-time travel and traffic information, details of parking spaces and weather conditions, office-based facilities (such as paging, email, and limited web browsing), collision avoidance warnings, intelligent cruise control, and lane keeping.

Concerns have been expressed that drivers will be overwhelmed by all the novel functionality on offer within their vehicles (e.g. Alm, Svidén & Waern, 1997). Verwey (1990) expresses such fears quite adeptly, when he notes that drivers may be, "snowed under a myriad of flashing warning lights, demanding speech instructions, vibrating pedals, automatically turning steering wheels and flickering devices" (p.7).

There is a clear need for human factors advice to aid in the design of *integrated* in-vehicle HMIs. Unfortunately, a recent literature review revealed a paucity of research in this area, although it is possible that general psychological principles and knowledge gained in the aerospace industry may be applicable - Ross, Burnett, Graham, May and Ashby (1997). An important issue in the immediate future for the route guidance function will be the integration of traffic and travel-related information within the HMI (Fairclough & Ward, 1995).

The greatest challenge ahead for human factors researchers with respect to HMI integration will concern adaptation, that is, on what basis can an estimate be made in real-time of the likely workload that a driver is experiencing, and what are the implications then for the presentation of information? There has already been some major work investigating adaptive systems, although many questions remain to be resolved prior to such systems becoming a reality (Michon, 1993).

10.3.2 Map database enhancements

The use of more advanced storage mediums, such as Digital Versatile Disks (DVDs), will enable the inclusion of a wider range of more detailed and accurate information within the map databases of the future (O'Shea & Schuman, 1997). In particular, DVDs will also be capable of storing digitised photographic images of junctions. In Japan, route guidance systems that present images of this kind are beginning to emerge onto the market (Pioneer Web site, 1998, June). Evidently, such developments are extremely pertinent to the concept of context-based navigation.

Such enhanced information may also be used in conjunction with radar sensing to provide safety-related warnings or to affect the control of the vehicle. For example, database knowledge regarding upcoming road events (e.g. sharp turns, steep hills, changes in road surfaces, lane widths, etc.) may assist in suspension adjustment, traction control, headlight orientation, and appropriate steering and speed control for the vehicle (O'Shea & Schuman, 1997).

10.3.3 Novel displays

Head-Up Displays (HUDs) have been available as factory equipment in some American and Japanese cars (primarily to present speed information and warnings) since the 1988 model year. The use of HUDs for presenting route guidance information is widely predicted for the future (Zhao, 1997; Beyerlein, 1995; Ward & Parkes, 1994), although many human factors issues remain to be resolved regarding the application of this technology within vehicles (see the review in Appendix 2A).

With respect to the development of context-based route guidance systems, the combination of a HUD together with a conventional Head-Down Display (HDD) may be used to differentiate between information relevant to different stages of the navigation task. For instance, 'Identifying' information could be presented to the driver on a HUD, whereas 'Confirming' information could be made available on a HDD.

It is forecast that large re-configurable high-resolution displays will become common place within vehicles in the coming years (Kamfjord & Holter, 1992).

Such displays will potentially enable much more sophisticated information (including that which is context-based) to be presented to the driver. With respect to route guidance systems, large displays have recently been used in Japan to present map information and turn-by-turn guidance within a split screen simultaneously (Crawford, 1997).

10.3.4 Road signs

The future development or otherwise of road signs within the environment may affect the design of HMIs for route guidance systems. Gale (1996) points out that, with the advent of mass marketed in-vehicle route guidance systems, road signs may become redundant. Systems need not make any reference to road sign information (e.g. "turn right in 300 metres") and, as noted by Gale, there would be significant cost savings in not having to construct and maintain signs.

Conversely, some recent technological developments in Japan have raised the potential for future intelligent road signs, in which different information is provided to drivers dependent on their chosen route (Akamatsu & Daimon, 1997). These road signs (located at junctions) emit light with a flashing pattern that varies for each direction on the sign. A liquid crystal shutter on the vehicle's windscreen only allows light to pass which is relevant to the recommended route (as specified by an in-vehicle planning unit). Synchronisation may be achieved via a communication link between the vehicle and sign or via the use of precise clocks.

10.3.3 Graphics handling

Superior graphics handling abilities have enabled the creation of 3D views of the driving environment (McCulloch, 1997, January/February). For example, in the Bird View™ system a simulated map view of the drivers' surroundings and recommended route is given which is equivalent to that seen from a point above and behind the vehicle (looking down at an angle of approximately 16 degrees) - Watanabe, Nakayama and Kishi (1996). Such an HMI potentially enables a much wider range of landmarks and other road features to be presented within a single map view without requiring the driver to manually change scales. Consequently, they are most of use for supporting driver orientation. Watanabe et al. provide some evidence that drivers prefer such graphics to plan view representations, but to date, there are no experimental studies in the open literature that have addressed the objective benefits of such views.

Lately, prototype software which manipulates digitised map views has been created as a means of providing simplified schematics of junctions and the surrounding roads (Anonymous, 1998, January/February). The resulting maps are similar to the 'network' maps used for underground train systems and could, in principle, enable drivers to use maps more effectively within route guidance systems.

10.3.4 Use of automatic speech recognition

Advancements in the capabilities of automatic speech recognition (ASR) software have created the potential for the widespread use of vocal input methods within vehicles. As noted recently by Graham and Carter (1998), "the task of safe driving could clearly benefit from a transfer of loading from the over-burdened visual-manual modality to the auditory modality" (p.2).

With respect to the design of HMIs for ASR-driven route guidance systems, there is a fundamental need to establish whether basic driver-system interactions, such as inputting a destination, repeating voice messages, calling up a map view, etc. are permissible whilst the vehicle is in motion. Clearly, it is also important to establish what the optimum dialogue method might be for different in-vehicle tasks, given the numerous variables that have been shown to have an influence on the efficiency of ASR (Leiser, 1993; Krahmer, Landsbergen & Pouteau, 1997).

ASR will potentially enable greater interaction between the driver and the route guidance system. With regard to issues of context-dependency, it can be envisaged that drivers may be able to request increased context when they require it (e.g. "how far away is the next turning?", "where is my destination?", "which landmarks are coming up?", etc.).

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APPENDICES*

*** Appendices are numbered to allow easy back reference. For example: Appendix 2A is the first appendix originating from Chapter 2; Appendix 4B is the second appendix from Chapter 4, etc.**

APPENDIX 2A

Literature Review - The presentation of route guidance information

Introduction

There are numerous design issues concerning the presentation of route guidance information to drivers. These have been grouped under four headings in this appendix: the choice of modality, the format of navigation information, the use of head-up displays, and the scheduling of route guidance information. Many studies have concerned themselves with issues across these headings, and so will be cited in each relevant part.

The choice of modality

There have been a large number of empirical studies which have addressed the question of which modality/ies should be used for presenting route guidance information. Indeed, it is likely that this is the single issue most tackled within previous research. Studies can be broken down into four distinct types, based on the experimental conditions that are compared:-

(1) Visual only vs auditory only

(2) Visual only vs visual and auditory combined

(3) Auditory only vs visual and auditory combined

(4) Visual only vs auditory only vs visual and auditory combined

The majority of studies on this topic are of type 1 or 2 - most frequently, visual information alone has been contrasted with visual and auditory information. There are few studies of type 3 or 4, and, as a result there is little knowledge regarding the merits of auditory information alone over visual and auditory information.

As a further point, it has been noted that drivers possess five input channels or modalities which could potentially receive navigation information, i.e. visual, auditory, tactile, kinaesthetic, olfactory and gustatory (Alm, 1993). Comparisons have only been made between the visual and auditory modalities, and it is possible that otherwise neglected resources could be explored in future research.

1) Visual only versus auditory only

The most obvious and universal attraction of the auditory modality, as stated in the literature, is that associated with no visual distraction (Zhai, 1991; Kishi & Sugiura, 1993). This is an important consideration, given that the vast majority of information required for driving is visual (Hartmann, 1970; Rockwell, 1972). With respect to effects on driver behaviour and performance, the majority of the studies described below have found the sole use of the auditory modality to be more favorable than visual information only.

Walker, Alicandri, Sedney and Roberts (1991) conducted a simulator-based study which investigated the effects of different complexities of information within the visual and auditory modalities. This study employed a factorial design in which 126 subjects, broken down into three age groups and split by gender, used one of seven different navigation information sources. Three of the sources were visual only: an electronic map display; textual guidance; or simple arrows. A further three aimed to mimic the different complexities of the visual information conditions using the auditory modality. Use of a paper map acted as a control condition. The different auditory conditions performed generally better than their visual counterparts, in terms of navigational errors, and speed reductions under high load situations. However, experimental effects were found to be stronger due to the different information complexities, rather than modality per se.

In another simulator study conducted by Srinivasan, Landau, Hein and Jovanis (1994), 17 male subjects in the 18-35 age bracket used each of the following modes of route guidance: an in-vehicle map display only; an in-vehicle symbol-based display; a head-up symbol-based display; and voice only instructions. In this study the voice only instructions led to the shortest reaction times to external traffic-related events (e.g. crossing vehicles), followed closely by the head-up guidance display and the in-vehicle map display. The data for perceived workload (NASA-TLX) and subjective preferences showed a similar pattern.

The results of road-based studies largely bear out these results. For instance, Van Winsum, Knippenberg and Brookhuis (1989) employed a repeated measures methodology to compare two conditions: use of a paper map with a highlighted route; and use of voice directions. 16 subjects took part, split by gender, with a mean age of 30. The two matched routes used in this study were short, lasting only 5 minutes and involving nine turns. Not surprisingly, voice instructions were found to hold considerable advantages in relation to the use of a paper map. Subjects made less navigational errors using the voice, they took less time to complete a journey and made more glances to their rear view mirror (indicating greater spare capacity). This study is one of few to employ psycho-physiological techniques, and it was found that the voice instructions led to reduced heart rate variability as compared with the use of a paper map.

Verwey and Janssen (1988) conducted a road-based study in which 36 male subjects, aged 22-45, used either simple visual arrows, simple voice directions (e.g. "go right"), or a memorised paper map to navigate. There were no differences between the visual only and auditory only conditions, in terms of subjective workload (the SWAT technique) and journey time. However, those using the auditory only system made significantly less errors, and, according to deceleration profiles on the approach to junctions, 'drove in a smoother way'.

In a study conducted by Green, Williams, Hoekstra, George and Wen (1993b), 43 subjects, of which 24 were younger (18-30) and 19 were older (60-76), drove a single route in the city of Michigan USA using route guidance information provided by either: a head-up display; an in-vehicle display; or voice instructions. The route contained 19 turns and included highways, city roads and residential roads. Similar to Srinivasan et al., the majority of subjects were found to prefer the voice only guidance over the visual-based information sources. Few navigational errors were made, although most were made in the voice only condition. These predominately occurred at two complex junctions (one where three roads converged, and another where two streets had similiar names and appearance).

Although the report does not make this assertion, the result could be considered evidence that voice messages alone may be insufficient for describing the action to take at manoeuvres with high spatial complexity. In these cases, it would seem that a visual display is required to provide additional information. The difficulties of using simple auditory commands to describe the direction to take at complex junctions has also been pointed out by Alm et al., 1992, and Dicks, Burnett and Joyner (1995).

Parkes and Coleman (1990) revealed further disadvantages with voice only route guidance. They compared the effectiveness of voice simulation, directional symbols and printed text in a simulated route guidance task with ten subjects (split by gender, aged 20-45), and found voice simulation to be the best method to use (in terms of task completion times and subjective preference). However, there was no difference in error rates between the conditions and some subjects complained of being 'paced' by the auditory commands. Ashby et al. (1991) also found that the LISB/Ali-Scout route guidance system was associated with increased temporal demands, attributing this to the pacing aspect of a system employing voice messages. Parkes and Coleman also found that a number of uncorrected errors were made in the voice only condition. Such a result suggests that drivers may be prone to following voice messages 'blindly', and, as a consequence might not receive valuable feedback regarding navigational errors.

To date, the most controlled investigations of the relative merits of the visual and auditory modalities have been made by Verwey (1989 and 1993). He found evidence that it is the format of route guidance messages, rather than modality, that dictates the speed by which they can be interpreted. Verwey carried out two lab-based studies comparing verbal and spatial format route guidance instructions. In both studies, whilst under severe perceptual-motor load (via a tracking task), subjects (all males aged 20-40) were asked to interpret route instructions against slides depicting real world junctions. Route instructions were composed of either auditory/ verbal (eg 'turn left' in spoken language); visual/verbal (eg 'turn left' written on a screen); or visual/spatial (eg an arrow on a screen) information.

Verwey found that subjects responded most quickly when presented with auditory/verbal messages and least quickly with visual/spatial messages. However, he found no significant differences in response times due to the modality incorporated. He believed the results could be attributed to subjects recoding spatial information (ie the arrows) into verbal memory codes for better retention prior to the presentation of the junction (Meyers and Rhoades, 1978). Unfortunately, Verwey did not include an auditory/spatial condition (e.g. a tone to left or right), or combinations of different format/modality arrangements (e.g. an arrow and the word right/left).

2) Visual only vs visual and auditory combined

Given the problems cited with respect to each of the single modalities, it is not surprising that there have several studies which have investigated the potential of using a combined visual and auditory interface. Comparisons of this type in the literature typically reveal significant advantages in using a combination of visual and auditory information.

Labiale (1990) conducted a road study in which 32 subjects, controlled for age (range 20-63), education and gender drove unfamiliar routes using a map display together with either textual or auditory guidance. No details are given regarding the nature of the routes used in this study. The map plus auditory condition was associated with less visual demand (less glances and shorter duration glances). In addition, the map plus auditory condition was by far the most preferred by subjects, a result which was confirmed in a later study (Labiale, 1992). However, an advantage for visual information over a combined use of modalities was found in the initial study. Drivers were best able to recall the route they had driven with the map and written instructions, predominately because repeated glances could be made towards the written instructions to aid in the retention of information.

Broad agreeement for these results was found in a road-based study by Kishi and Sugiura (1993). They compared the use of of visual route guidance information with visual and voice instructions. Visual information was map-based between manoeuvres and symbol-based on the final approach to a turn. Few subjects took part (four in total) though, and so the results must be treated with caution. As for Labiale, there was less visual distraction in the visual and auditory condition compared with the use of visual only information. Closer inspection revealed that the difference was in terms of glance frequency rather than glance duration, i.e. less glances were made with visual and auditory route guidance, not shorter glances. In addition, subjects were found to have a lower heart rate when using the visual and auditory route guidance instructions.

Similar results were found in the controlled simulator environment by Srinivasan et al., 1994 (also reported in Srinivasan & Jovanis, 1997). 18 subjects were employed, all in the 30-40 age bracket, split by gender and driving experience to use each of three forms of navigation information: an in-vehicle electronic map display only; a head-up symbol-based display together with the map display; and voice instructions together with the map display. A paper map served as the control condition. The combination of the voice and the map display led to least perceived workload (using the NASA-TLX), and least navigational errors. This condition was also the preferred option, although it is noted that some subjects commented that they found the voice messages to be irritating and wanted the option of turning them off. The fact that audio messages can be perceived as intrusive has also been reported by Stokes, Wickens and Kite (1990).

A road-based study by Burnett and Parkes (1993) confirms these positive attributes of a combined interface. 16 subjects (split by gender, predominately in the 20-30 age group) drove two matched routes, one using simple visual route guidance symbols together with a graphical distance to the next turn, and one with the same visual information plus an additional simple voice instruction. In addition, half of the subjects were provided with a pre-information message, warning them of the nature of the oncoming manoeuvre and distance remaining (given after the previous turn).

In this study, when both visual and auditory information was presented, fewer single glances were made and less time was spent glancing towards the route guidance device, compared with the display of visual information only. Overall mental workload values were reduced (according to the NASA-RTLX and Modified Cooper-Harper scales), and drivers rated the combined mode as easier and less stressful with which to navigate. Furthermore, they overwhelmingly preferred it to the visual information only conditions. However, despite the simplicity of the auditory messages, several subjects commented in the post-trial interview that the transient nature of the voice required sustained concentration. Other authors have also raised this issue (Southall, 1988; Parkes & Coleman, 1990), although it must be noted that the driver workload values reported in this study and in others (e.g. Lansdown, 1997; Srinivasan et al., 1994) do not bear the concerns out.

A further point that has been raised with respect to the use of a dual-modality route guidance system is that it may help to ensure that a system is usable for elderly and/or disabled drivers who experience reading difficulties or hearing impairments (Ross et al., 1995; Burnett & Joyner, 1996). As a related point, it is felt likely that route guidance systems may be used with a single modality, either by disabled drivers, or by those who choose not to have the voice/display on. This seems to be a topic completely ignored in the literature, and it will be important for human factors research to provide guidance to ensure that systems can adapt to single modality presentation.

3) Auditory only vs visual and auditory combined

The literature review has only revealed one study of this type. In a repeated measures design, Fastenmeier, Haller and Lerner, 1994 employed 16 subjects, split by gender, to drive unfamiliar routes in the city of Munich, Germany using two different modes of route guidance: auditory only (e.g. "turn left next junction"); or visual (symbol-based) and voice. Driver behaviour and performance were contrasted with two control conditions, use of a paper map (with preferred strategy), and instructions from a passenger, a "co-pilot". Two experimenters sat with the subject: one recorded the navigational errors he or she made using a classification scheme developed in an earlier study, and gave a safety rating (on a 1-5 scale) for each error; the second recorded a number of measures, e.g. journey time/distance, use of indicators, number of overtaking/lane change manoeuvres. This form of experimental approach provides considerable context to safety-related driver behaviour, although one might question the intrusiveness of having two observers rating the effectiveness and efficiency of a subject's driving.

In this study, use of the paper map consistently performed worst, the co-pilot best, and the two route guidance systems 'inbetween', in terms of journey time, distance, and navigational errors. Few differences were found between the two route guidance system conditions, although it was observed that the voice only route guidance system led to confusion at complex manoeuvres (e.g. ring-road junctions with multi-lane approaches and a number of possible options). This highlights the point made earlier regarding the requirement for spatial presentation of navigation information in certain cases. The most interesting result of this study was that use of the visual and auditory route guidance system led to significantly more right of way violations (e.g. "red light errors, endangering pedestrians and cyclists and illegal turnings"), as compared with the co-pilot condition. The experimenters attributed this finding to the visual distraction that arose in this condition.

4) Visual only vs auditory only vs visual and auditory combined

The literature review has only revealed two studies which have compared all three possible experimental combinations when investigating the relative merits of the visual and auditory modalities.

One of the earliest and most cited empirical route guidance studies addressed the issue of modality of information presentation. Streeter, Vitello and Wonsiewicz (1985) conducted a field study in which 57 subjects (a split of people who drove extensively as part of their work, and those who did not) attempted to follow routes in unfamiliar environments using customised paper maps, voice directions, or both. They found that drivers who listened to instructions took less time, drove less distance and made about 70% less errors than those who used maps. Perhaps surprisingly, the performance of those drivers who used both maps and voice messages was lower than that for voice alone, but was better than those who used just maps. The authors partly attribute this result to the combined modality interface providing too much information for drivers.

Some authors have cited the findings of Streeter et al. as an argument for caution with respect to use of the combined visual and auditory modalities (e.g. Green, Levison, Paelke & Serafin, 1995). However, in commenting on this issue, it must be noted that Streeter et al. used maps (i.e. complex spatial information) as the visual component of the study. It has been reported elsewhere (section 1.3) that many people experience considerable difficulties in using maps, and, therefore, it is possible that results may have been different if symbolic or text based visual guidance was presented.

A more recent study was conducted in the simulator environment by Lansdown (1997). 21 subjects (13 male and 8 female; aged 18-37) drove three different routes using each of the following route guidance methods: visual information (simple left/right arrows); auditory information (instructions such as "next left"); and visual and auditory combined. In addition, a route was driven using an 'ideal' control condition, following a car in front. Routes were balanced in terms of length and number of left/right turns.

In Lansdown's study, the visual only interface was associated with the highest number of navigational errors, and highest subjective workload (NASA-RTLX). In addition, the use of this modality was associated with more glances towards the display in comparison with the use of the combined visual and auditory information. There were no differences, in terms of errors and workload between the auditory only interface and the combined interface. However, the visual-auditory display was the most preferred option. The author raises a number of issues of concern regarding the use of voice messages within the vehicle environment, including the need to account for ambient noise in the vehicle, and deciding on the content of information for auditory route guidance instructions.

The format of navigation information

In this context, there are two basic 'formats' of route guidance information presentation:

(1) *Map-based* - in which a collection of predominately spatial relations are visually presented to drivers[1]. Stokes et al. (1990) describe two potential map displays: the earth fixed/referenced, in which the car symbol moves around a fixed map (usually shown to be North up); and ego-centred, in which the map display rotates around the static car symbol. The latter of these is also known as a moving map display.

(2) *Turn-by-turn* - in which ego-referenced instructions/advice (visual and/or voice) are provided at each relevant decision point. Information presented in this way is predominately verbal in nature[2].

This section deals primarily with issues concerning these two overall formats. The topic has been well discussed in the literature, however, there have been relatively few direct comparisons between the two formats. This is largely due to the difficulty in simulating a map-based system, and, as a consequence, many of the most relevant studies addressing this issue have been evaluations of actual or prototype products.

Experimental studies

Many of the earliest studies addressing the usability of navigational aids were conducted by the Human Factors research team at Virginia Polytechnic Institute and State University in the mid to late 1980s. In their most relevant study, Wierwille, Antin, Dingus and Hulse (1989) investigated the effects of three navigation methods (memorised route, paper map and electronic map-based system - ETAK™) on driver behaviour. As was the case with many of the early map systems, no highlighted route was provided, and subjects were free to choose the route they felt was most suitable. The electronic system was associated with significant visual distraction; on average, 33% of the total journey time was spent looking at the device, compared with none for the memorised route and 7% for the paper map. Indeed, two people (both females over 50) spent over 50% of driving time looking at the display. The authors suggest some reasons as to why such high visual demand occurred for the map-based system. These included the facts that subjects were relatively novice users of the system, new map information was constantly scrolling onto the screen, and the display was in a convienent position for glancing.

However, this study found no differences in lane exceedences and brake accentuations between the three conditions; it was therefore concluded that the map-based system could be used 'effectively' by the driver. This was based on the view that drivers demonstrate appropriate adaptation in their visual scanning patterns for high demands in the driving task (also suggested by Rockwell, 1988).

Labiale (1989) was also active in evaluation research during this time. In his work, it was possible to vary components of the map display's interface. Thus he investigated the behaviour of 60 subjects (split by gender with a wide range of ages: 20-63) when using a map-based system, either alone, with an auditory message, or with equivalent written text. In contrast to Wierwille et al. he found that use of the map-based systems did influence driving performance: drivers strategically reduced their speed when consulting such displays, presumably to cater for increases in mental workload due to the introduction of the in-vehicle

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[1] some verbal information may inevitably be given, e.g. street/place names, road numbers
[2] some spatial information may be present within the HMI, e.g. junction layout symbols, distance countdown bars

display. Such a result has also been found by Van Winsum et al. (1989) with respect to the use of paper maps with a highlighted route.

Burnett and Joyner (1993) also found that use of a map-based system (an early version of the Bosch TravelPilot™ showing a highlighted route) can result in significant effects on the control of the vehicle. In the first of two road-based evaluation studies (see also Burnett and Joyner, 1997), they used 24 subjects in the 40 to 60 age range, and compared use of the system with both a subject's preferred method of navigation (maps, notes or a combination of the two) or verbal instructions given by the passenger.

Burnett and Joyner found that subjects exhibited greater variability in their steering wheel movements whilst using the route guidance system. This occurred very noticeably when approaching the required exit on a dual carriageway where large amounts of time were spent with the eyes off the road (as high as 75% of a two minute period). As the authors point out, this gives some cause for concern, as drivers were having to make more adjustments to the steering to correct path deviations caused by looking away from the road ahead (ie drivers were wavering within their lane). Furthermore, use of the route guidance system led to over twice as many navigational errors being made as compared with drivers' use of paper maps or notes, and reduced the time spent looking towards the windows, mirrors and dashboard. This latter result replicated that found by Ashby et al. (1991), and supports Rumar's (1988) theory on the side-effects of visual workload (ie that 'spare' visual resources are allocated to the display at the expense of other areas in the driver's visual scene).

Reflecting the types of system being developed by manufacturers, more recent studies have compared the use of map-based navigational aids with those providing turn-by-turn instructions (visual and/or voice).

For instance, Ashby, Fairclough and Parkes (1991) evaluated two prototype route guidance systems in a road-based study in Berlin. One system provided simple symbolic guidance together with voice messages (LISB/Ali-Scout); the other provided a map view of the surrounding area (Bosch TravelPilot™). As for the ETAK system, this version of TravelPilot gave no highlighted route. 24 subjects (15 less than 30 years old; 9 older than 55) took part in a repeated measures design. Subjects using the TravelPilot system attended to the display for significantly more of the total time in motion (14.4%) than with LISB (8%). Furthermore, subjects perceived a higher level of mental workload when using this map-based system, according to the NASA-TLX. However, the LISB system was associated with increased temporal demand, a reflection on the pacing aspect of turn-by-turn systems, particularly their voice output (as expressed in the previous section).

Färber and Popp (1991) conducted a simulator study which included a condition in which an electronic map was combined with directional symbols. Little information is provided regarding the experimental set up, but subjects drove on simulated rural roads using either a heading-up electronic map display (with no highlighted route), the same electronic map together with a simple route guidance symbol (i.e. left/right arrow), or the map display with a highlighted route to follow. Use of a paper map served as a control condition. Least navigational errors and fewest display glances arose in the electronic map plus route guidance symbol condition. Most errors occurred when subjects used the paper map, although many errors also arose when subjects used the electronic map with no route guidance. The most glances also occurred for this latter condition.

Obata, Daimon and Kawashimo (1993) also made comparisons between different types of map display. In a repeated measures design, nine male students drove unfamiliar routes in Yokohoma, Japan using each of the following: an electronic map display which accurately represented the layout of the roads together with a simple arrow; a 'deformed' map display in which the layout was simplified together with a simple arrow; and the simple arrow solely. The deformed map display and arrow was preferred by eight of the nine subjects. Few errors occurred in this study (eight in total), of which six arose in the 'complex' map plus arrow condition.

The two simulator studies conducted by Shrinivasan, et al., 1994 (described earlier) are relevant to this issue. The authors note that despite their complexity, the map-based component of the various interfaces was consistently rated favourably by subjects. Information content, rather than format was felt to be a factor, since subjects reported that they liked to know the number of streets prior to their turning. This information was absent from the turn-by-turn systems.

In Walker et al.'s (1991) simulator study (described earlier) some control was made for differences in information content. Comparisons were made between route guidance systems offering three different levels of information complexity within either the visual or auditory modality. Subjects were found to reduce their vehicle speed to cope with greater information complexity (also found by Labiale) and to pay less attention to an instrument gauge monitoring task. This effect was strongest for the paper map and electronic map conditions. However, similar to Antin et al., they found no differences with respect to drivers' lateral placement.

In Walker et al's study, a similar number of navigational errors arose in the paper map control as arose when subjects used the map-based system. However, the greatest number of errors occurred for those subjects using the simple arrows, mainly because no alerting tone was given, and subjects failed to monitor the display sufficiently to notice new information.

In a recently reported evaluation study (Burnett and Joyner, 1997), the use of turn-by-turn systems led to some negative effects on driver behaviour and performance. In a road-based trial, 24 subjects in the 40-60 age range drove three routes using either two different turn-by-turn systems, or instructions given by the passenger (the 'ideal' control condition). It was found that both of the systems led to significant visual demand, for instance, the percentage of journey time in motion spent glancing towards the systems was approximately 17%. A number of navigational errors also arose when subjects used the turn-by-turn systems, primarily due to one of, or a combination of three reasons, either (1) difficulties encountered in using distance countdown bars, (2) the presentation of limited/inaccurate environmental cues, or (3) poor message timing (late) on the approach to manoeuvres. With respect to the third point, late presentation of information was observed to lead to a number of undesirable driving behaviours, for instance, late lane changing, and late/no indicating.

Discussion points

Its is clear from the above summaries of studies addressing this topic that map-based displays pose a number of problems for drivers. Schraggen (1991) carried out a formal review of studies which compared map-based navigation systems with the use of turn-by-turn route guidance (he referred to the latter as simple arrow/voice systems). Seven studies were included and he used one common dependent variable, navigational errors. A calculation was made in an attempt to account for differences in the experimental routes used in studies. A figure was calculated for the percentage reduction in errors caused by a particular type of system as compared with a control condition (usually paper maps).

In his review, Schraggen found that in all the studies in which the route guidance system was turn-by-turn, there was a reduction in navigational errors as compared with the control (ranging from 41% to a 100% reduction). The only study in which no reduction arose involved the use of a map-based system, the ETAK navigational aid (Wierwille et al., 1989). On the basis of this comparison, Schraggen concluded,

"Map-like displays should not be used in navigation systems, if we want to improve upon conventional maps" (p.8).

The following table expands on Schraggen's work, by including more recent studies and details regarding the nature of the map-based and turn-by-turn systems that may have a bearing on the results are also shown. The study by Schraggen (1990), originally included in his review has been deliberately omitted from the table below, since the 'navigation system' in this work was neither a map-based or turn-by-turn system. In effect, the system was a modified control condition (a customised memorised paper map).

	% reduction Map-based vs 'Paper map' control	% reduction Turn-by-turn vs 'Paper map' control	System details
Streeter et al. (1985)	/	41	TBT=voice only
Van Winsum et al. (1989)	/	100	TBT=voice only
Verwey & Janssen (1988)	/	78/60	TBT=Voice only/ visual arrows
Wierwille et al. (1989)	0	/	Map=display with no route guidance
HUSAT (1989)	/	47	TBT=text instructions
Pauzié & Marin-Lamellet (1989)	/	84	TBT=visual arrows
Färber and Popp (1991)	25/38	65	Map=display with/without route guidance; TBT=map + arrow
Walker et al. (1991)	14	Between +100 and -14	Map=display no route guidance; TBT=range of different systems
Burnett & Joyner (1993)	-130%	/	Map=display no route guidance
Fastenmeier et al. (1994)	/	33/41	TBT=visual and aud/aud only

Table 2A.1 - Percentage reduction in navigational errors for a number of different studies (based on Schraggen, 1991) TBT = Turn-by-turn

Observation of the new studies in Table 2A.1 bears out the conclusions of Schraggen, i.e. that map-based route guidance leads to reduced navigational performance in relation to turn-by-turn guidance, and offers few advantages in relation to existing methods. In Walker et al.'s study, the principle reason why such a range of performances arose in the turn-by-turn conditions was the types of information contained in the directions, highlighting the importance of information content. The +100% score was associated with the simple left/right voice instructions. However, it must be noted that this was a basic simulated environment - it is likely that greater contextual information would be required in more complex situations.

The above review is obviously limited in that it has been based on a single effectiveness measure, navigational errors. It would be useful to conduct a similar exercise using efficiency measures, such as visual behaviour or driver workload. However, examination of the literature reveals that comparisons of this kind are problematic, given the variety in measurement techniques, and routes used.

Several specific points are put forward in the literature as to why map-based navigation consistently leads to inferior performance in relation to the use of turn-by-turn directions.

Firstly, it has been pointed out that map-based systems provide considerable redundant information (Alm, 1993; Ross et al., 1995). Drivers, therefore have to search the display for information relevant to the navigation task, and then match information to the road view. In turn-by-turn systems information is only presented which is relevant to the oncoming manoeuvre, i.e the system filters, rather than the driver. This aspect of map-based systems largely explains the increased visual demand that has been observed, particularly the increases in glance durations.

Secondly, in map-based systems new information is constantly scrolling onto the screen. The system therefore requires continued re-checking to update progress (Ashby & Parkes, 1993). This aspect would help to explain why glance frequency has been found to increase for such systems. In addition, it may be argued that the constant movement in the periphery of drivers' vision may be in itself a source of distraction, although this view has not been expressed in the literature.

Thirdly, it has been argued that the map format is not appropriate for providing information relevant to specific navigational decision making. The highly spatial nature of maps makes them most suitable for presenting information concerning the objects and features of the physical landscape (described as the static macro environment), and less suitable for presenting information concerning the aspects relevent to the driver (the static micro environment) - Petchenik (1989).

Finally, it has been noted that, according to multiple resource theory (Wickens, 1992), the use of spatial information sources such as maps for navigating conficts with the predominately visual-spatial task of driving (e.g. speed estimates, spatial relations of other road users) - Wetherell (1979). This theoretical perspective would explain the increases in navigational errors and workload values experienced by many of the subjects in the studies described above.

In contrast to the above, positive views have been expressed. It has been pointed out that the on-going presentation of navigation information by map-based systems is more consistent with the self-paced nature of the driving task (Ross et al., 1995; Alm, 1993). Verwey and Janssen (1988) have argued, using the principle of display proximity (Boles & Wickens, 1987), that the intake of self-paced visual navigation information may become more integrated with the driving task. As a result, one would expect improved performance over time for self-paced visual information, in comparison with the use of turn-by-turn instructions. Unfortunately, the few longitudinal studies in this area so far means that such hypotheses have yet to be tested.

An additional advantage for map format information is that it can provide an overview of the drivers' surroundings, including the route that will be taken (Ross et al., 1995). Such information is of most use during the pre-trip planning stage of the navigation task. HUSAT (1989) provides some empirical data to suggest that drivers do feel the need for overall views. Mark (1989) cites the findings of surveys which have found that many drivers use a map at the start and end of a journey and rely on turn-by-turn directions as much as possible during journey.

Use of Head-Up Displays

It is likely that the first generation of route guidance systems will incorporate an in-vehicle display. With the advent of further Intelligent Transport systems (e.g. collision avoidance, traffic information, driver status monitoring), there will be increasing demands on dashboard 'real-estate'. An attractive solution for designers therefore is to utlise technology developed in the aviation and military fields, and to present information in line with the driver's natural field of view, i.e., as head-up.

The use of Head-Up Displays (HUDs) has received a reasonable amount of attention in the literature. The intended purpose of such displays is to allow drivers to continue attending to the road ahead whilst taking in information more quickly from a display (Ward & Parkes, 1994). Therefore, they may be most applicable to situations in which the visual modality is highly loaded (e.g. urban driving), and for older drivers who experience difficulties in rapidly changing accommodation between near and far objects (Burns, 1997b).

Some preliminary empirical work on this topic has shown some advantages for the driver in presenting route guidance information via HUDs. For instance, James, Eheret and Philips (1995) conducted a simulator study in which 48 subjects (split by gender, and of a wide range of ages - 25-81) viewed a computer generated road scene and pressed a button as soon as they recognised a junction. Route guidance information (simple symbols) was presented either as a head-up image or on a traditional in-vehicle display. In this study, the HUD position was preferred by all subjects. However, there were no clear advantages for the HUD over the in-vehicle display in terms of reaction times and response accuracies.

In a further simulator experiment, Green and Williams (1992) employed 12 subjects who were shown slides of residential intersections photographed from the driver's viewpoint, and simultaneously shown slides of a navigation display. Subjects indicated if the two images were of the same or of a different type of intersection, and their response times, error rates and subjective data were recorded. The views were given either on a HUD or an in-vehicle display. In contrast with James et al., it was found that reaction times with the HUD were consistently better than for the in-vehicle display (average: 1524 vs. 1630 ms).

However, despite these positive indications, there are dangers in simply translating a technology from one environment to another, and several human factors issues have been raised in the literature (summarised by Newman, 1987; and Ward & Parkes, 1994) which remain to be resolved.

(1) Because of their attractiveness to car designers, there may be a temptation to display too much information, potentially masking critical information outside the vehicle. This is most important in the automobile where rapidly changing colour contrasts occur.

(2) The image may disrupt the familiar scanning patterns associated with traditional instrumentation. A related problem is the difficulties that drivers may find in switching their attention between head-up and in-vehicle displays, in order to extract the information they require.

(3) A further point of concern refers to the difficulties that may occur through focusing attention on one information source outside the vehicle, whilst ignoring another, and in switching attention rapidly between the two sources.

(4) There is considerable evidence to show that the population varies in its ability to identify relevant objects within an embedded context (Goodenough, 1976). As a consequence, one may hypothesise that certain drivers with low abilities in this respect (referred to as field dependent) would experience greater problems with using HUDs, and may benefit more from traditional in-vehicle displays.

(5) Finally, there is evidence that use of contact analogue HUDs (i.e. where the image is superimposed on top of the road scene) envokes a phenomenon known as perceptual tunneling (Bossi, Ward, Parkes & Howarth, 1997). As a result, there is a reduction in attention to peripheral areas, with potential consequences for driver safety.

Discussion - interaction effects

As one can see from the above, there have been many human factors studies which have tackled issues relevant to the presentation of information on a route guidance display. A criticism that can be levelled at many studies is a failure to realise that the relative performance of one route guidance HMI over another will be a function of the interaction between various components of the HMI, e.g. information type, modality, message format, display position. Studies generally have not balanced for particular aspects of the HMI when investigating an issue. This renders their research more concerned with *styles* of route guidance information presentation, and effectively negates any conclusions made with respect to one topic.

These problems in methodology are exacerbated by the fact that studies rarely explain in detail the content of the information presented to drivers. This is particularly the case for the auditory modality. Such a situation renders it difficult even to know the extent to which like is being compared with like. Both Verwey and Janssen (1988) and Zaidel and Noy (1997) have realised this confounding of results.

For instance, in Verwey and Janssen's initial study, they could not be sure if the voice results performed better than the simple arrows, as a result of message modality or format. Therefore, in subsequent studies (Verwey, 1989 and 1993), interaction effects were accounted for by utilising a lab-based environment and investigating the relationship between modality and format for a basic route guidance information type, direction of turn. Table 2A.2 shows examples of how format and modality can be related for this one information type.

		Sensory modality	
		Visual	Auditory
Information format (coding)	Verbal	Written word - *Right*	Spoken word - "*Right*"
	Spatial		Tone located to right of driver

Table 2A.2 - Relationship between message modality and format - Example for simple direction information

Scheduling of route guidance information

This section deals with two specific issues that have been addressed in the literature relating to the temporal aspects of route guidance information presentation:

(1) The timing of instruction presentation of the final approach to a manoeuvre.

(2) The 'stacking' of messages when manoeuvres are close to one another.

Timing on final approach

The timing of route guidance messages, particularly on the final approach to a decision point, is critical to system safety and acceptability (Ross et al., 1995). As discussed by Ross et al., and Alm (1993), if a message is given too early, then memory demands and increased mental workload may arise. Conversely, if timing is late, then this may lead to increased temporal demands on the driver. Such demands may then have implications for the safe and efficient control of the vehicle (e.g. late and sudden braking, late/no indicating).

Although some of the above problems have been borne out in the findings of evaluations of prototype systems (e.g. Ashby et al., 1991; Davis & Schmandt, 1989), to date, there have been few studies which have empirically addressed the timing issue. Some authors have discussed how route guidance messages could be related to the position of external cues or objects (e.g. road signs): Schraggen (1991); Kishi and Suguira (1993). However, this strategy neglects the fact that not all intersections are preceded by an appropriate road sign. Furthermore, there is a requirement for intelligence on the part of the route guidance system, i.e. for the map database to know the position of all relevant external cues.

A simpler and more desirable strategy (from a system designer's point of view) is to base the timing of an instruction on measurable criteria, e.g. the distance or predicted time remaining prior to a junction. Two key studies have taken this quantifying approach.

Ross, Nicolle and Brade (1994) conducted a road study in which 15 subjects (12 male, 3 female, of a range of ages (24-62)) drove a single route which took between 60 and 90 minutes to drive and encompassed 18 decision points (all turns off the current road). The study concentrated on the timing required for turn off roads because, as the authors point out, "timing is critical for the safe negotiation of such manoeuvres" (p.7).

An experimenter sat in the passenger seat and provided simple route guidance instructions on the final approach to each manouvre. A range of timings were utilised, based on the results of a pilot trial. From the point at which the message was given, up until the manoeuvre had been executed, various vehicle performance parameters were captured (speed, distance, onset of indicators, use of brakes), and subjects were asked to provide their opinion as to the timeliness of the message. A regression equation was formed based on drivers' subjective opinion as was to what consituted a 'timely' message, and it was found that timing could be based on vehicle speed alone. Other parameters, such as junction angle, turn direction or traffic density were not found to have a significant effect on optimum timing.

A similar study was carried out by Green and George (1995). 48 subjects were employed, split evenly into three age groups (18-30; 40-55; >65) and balanced for gender. Subjects were relatively experienced drivers, based on the number of miles driven in the previous year (average of 13K), and were described as 'moderately familiar' with the test area. The study took part in Michigan, USA, and encompassed main roads in business districts and residential roads. In this study, the junctions under observation were all left/right turns at traffic lights, although no indications are given in the paper as to why such manoeuvres were selected for study.

Two parts to the study were devised - in part 1, subjects were told that a left/right turning would be 1-2 miles away and to ask for confirmation on the final approach. In part 2, drivers approached a series of known junctions and were asked to inform the experimenter when they would like to be told which way to turn. The same junctions were then approached again using the recommended timing and subjects were told to state whether this timing was indeed satisfactory. In both parts the speed of the vehicle and traffic densities were monitored. The two parts generated similar regression equations, and Green and George report that the first method was better, since "it took less time per subject and yielded more data".

In some agreement with the results of Ross et al., speed was a prominent factor in both the regression equations. However, other factors were included in the equations, notably the individual factors, age and gender. As one might expect older drivers require route guidance messages to be presented earlier than do younger drivers. Unfortunately, no explanation is given in the paper as to why females may require messages to be given earlier than do males.

It is clear that the timing of 'final approach' messages is a complex issue that involves a number of interacting variables. In concluding this section, one might question if there is a need for computer-initiated message presentation at all. The use of driver-paced messages (as per Streeter et al., 1985) would remove the need to establish exact timing values, and would ensure better integration with the driving task (as discussed earlier). The constant visual display of distance-to-turn information, together with speech recognition, or steering wheel operated controls, would enable efficient requesting of new route guidance information.

However, some recent empirical work (Zaidel and Noy, 1997) places this assertion in doubt. The authors conclude on the basis of the results of two road-based studies that a simulated route guidance employing an automatic mode (system-paced messages) was associated with higher driver performance than a system in which the driver requested new information. This was found to be particularly the case for an auditory only system. As expressed by Zaidel and Noy, "the system can better anticipate upcoming decision points because it "knows" the road network, it frees drivers from having to decide and intitiate interactions, and it causes drivers to drive at a pace established by the system" (p.306).

'Stacking' of route guidance messages

Combining more than one route guidance instruction into a single message (termed 'stacking') has been considered to a useful way of preparing drivers for manoeuvres which are close to each other (Green et al., 1995; Ross et al., 1995). Alm and Berlin (1991) conducted a road-based experiment examining how many decision points to include within a single route guidance instruction. Three conditions were tested: level 1 - what to do at next manoeuvre only; level 2 - what to do at the next two manoeuvres; level 3 - what to do at the next three manoeuvres. A factorial design was employed such that each of 24 subjects (split by gender; age range 23-54) drove a single route in the city of Linköping, Sweden using one of the three levels of route guidance instruction (spoken by passenger). The route was short: approx. 6 km long, involving 15 decision points and taking less than 7 minutes to drive on average.

Level 3 led to significantly more requests for repeats, and was rated as more difficult, suggesting an excessive memory load. The relative performance of levels 1/2 was found to depend on the driving time between intersections. Based on an analysis of the data for each manoeuvre, the authors concluded that, if the driving time between intersections is less than approximately ten seconds, then a route guidance system should present information on both manoeuvres, i.e. 'stacking' should take place.

Conclusions

The conclusions to this appendix are given as a set of points, as follows:

- There have been a large number of studies addressing information presentation issues, notably the choice of modality (visual vs auditory vs combination) and the format of information (map-based vs turn-by-turn based). However, it can be very difficult to make definitive conclusions on these topics, given the failure by researchers to realise the confounding nature of variables within their studies.

- The evidence does suggest that a combination of modalities is the most appropriate means of presenting information, to best exploit the advantages of each medium. A combination of modalities has been found to lead to a variety of benefits for the driver, for instance: reduced navigational errors; reduced visual distraction; reduced objective or subjective workload; subjective driver preference; and improved route recall.

- Drivers experience a number of problems in using paper maps for navigation, and the translation of such a format to displays does not alleviate the situation. The predominately spatial map-based information provides considerable redundant information, can require constant visual checking for new information, and conficts with the largely visual-spatial task of driving. Turn-by-turn systems which are more verbal in nature do not suffer the same concerns.

- However, there are advantages in the presentation of map-based information. For instance, information is self-paced, and, as a result may, over time, become more integrated with the driving task. Furthermore, maps can provide an overview of the route to follow, a more strategic level of information which is important for driver confidence, and is inevitably absent from turn-by-turn directions.

- Head-up displays (HUDs) could offer a future solution for the display of route guidance information, provided such displays are appropriate for the driving environment with its complex, continually changing visual scene. Key human factors issues include the effect on driver attention, potential changes to normal scanning patterns, and the swapping of attention between the HUD, other in-vehicle displays, and the external road scene.

- The timing of route guidance instructions on the final approach to a manoeuvre is critical to system safety and acceptability. Studies have been conducted which have aimed to establish which variables most influence optimum timing, with some indications that vehicle speed is the most important factor. There is clearly a requirement for further work here.

APPENDIX 2B

Literature Review-General methodological issues

Introduction

There are numerous methodological issues associated with the investigation of the HMI for route guidance systems. Many of these are common across the different research questions, and the focus of this section is to provide an overview of the existing generic issues. For a more detailed discussion of methodological considerations, the reader is referred to the following reviews (Green, 1995; Zaidel, 1991; Parkes, 1991).

Research environment

The following diagram shows the main alternatives for the medium or environment in which route guidance research can be conducted, and the implications that use has for experimental validity and control (Parkes, 1991). The distinction between real road trials at a macro and micro level reflects research in which either a fleet of vehicles or a single vehicle are employed.

Increasing confidence that data correspond to real phenomena	Real road field trials (Macro)	Increasing control of variables and replication
	Real road test trials (Micro)	
	Test track studies	
	Dynamic vehicle simulations	
	Static vehicle simulations	
	Part task evaluations	

Figure 2B.1 - Options for research environments for route guidance studies

Table 2B.1 is a summary of the environments in which route guidance HMI studies have been conducted. A further category of 'surveys' has been added to reflect the use of this 'environment' in gathering basic data of relevance. The survey category includes direction giving studies such as Alm (1990), and Obata et al. (1993).

	Number of empirical studies
Real road field trials (Macro)	6
Real road test trials (Micro)	36
Test track studies	0
Dynamic vehicle simulations	11
Static vehicle simulations	9
Part task evaluations	6
Surveys	5
TOTAL	73

Table 2B.1 - Numbers of empirical studies utilising different environments

The table clearly shows a preference for use of the road-based environment when conducting human factors research concerning the HMI for route guidance systems. Although one might argue that this distribution is partly a result of the tools at the disposal of researchers (i.e. instrumented cars over simulators), strong cases have been made for the use of real road settings. For instance, Zaidel (1991) believes that road-based studies should be used for any research which evaluates the implications of a system for road safety. He suggests that traffic negotiation is critical to safety, and comments that, "real traffic environments are abound with natural occurrences of a wide range of driving events" (p.viii).

A study which demonstates some of the benefits of road-based studies made comparisons between the results obtained in a simulator experiment which used a video taped route and those from a road-based study employing the same route (Green et al., 1993a). Glance data from the simulator did not correlate with that collected on the road, and the authors concluded that the videotape method was not a good one for assessing different HMI options for route guidance systems. A variety of other problems with the use of a video image were stated, including: motion sickness, limited image resolution (making it difficult to view road signs and street names), and drivers' anticipation of turns based on the movement of the lead vehicle.

Test routes

The choice of test routes is of fundamental importance in route guidance research if the advantages and disadvantages of a particular system interface are to be revealed (Gstalter & Fastenmeier, 1991). However, the literature is surprisingly lacking in papers addressing this issue. A fairly informal approach is taken by Zaidel (1991), who argues that the evaluation of ITS from a safety perspective should include the use of high traffic volumes to ensure that "complex interactions between drivers" can occur (p.viii). However, no mention is made of how high such volumes of traffic should be.

Gstalter and Fastenmeier (1991) are the only researchers to examine systematically how test routes should be chosen. They argue that routes should be chosen with high degrees of complexity, forcing subjects to operate under conditions close to their resource limits, so that increases in mental demand will lead to reductions in performance related measures. To achieve such conditions, they recommend particular traffic situations that would be appropriate for the driver population under consideration. For example, if the intended subjects are experienced drivers, then they recommend test routes that have "high complexity and include inner city situations with signed junctions and minor priorities". Gstalter and Fastenmeier also argue that routes should be representative of the kind of trips likely to be driven with the navigating equipment (for the user population under consideration).

Unfortunately, inspection of the literature appears to reveal that there has been no use of Gstalter and Fastenmeier's recommendations, apart from that undertaken by the authors themselves in further studies (e.g. Fastenmeier, Haller & Lerner, 1994). Apart from a general lack of visibility within the research literature (this is a report written for the EC funded 'BERTIE' project), it is believed that practical considerations have rendered the application of this work problematic. For instance, researchers can be constrained by the roads and junction types available in the test area and the need for matched routes, as well as the route choice algorithms utilised by a given route guidance system.

Control conditions

The inclusion of a control condition is generally considered to be a basic requirement of experimental research (Coolican, 1994). A control provides baseline data which can be compared with the experimental condition, and enables other researchers to replicate studies and contrast results. However, observation of the literature in this area reveals that in many cases a control condition has not been included (e.g. Kishi & Suguira, 1993; Alm, Nilsson, Jarmark, Savelid & Hennings, 1992; Burnett & Parkes, 1993). A lack of consistency as to the control condition used is also apparent.

With respect to this second point, there have been a number of road-based studies in which drivers' use of paper maps has served as a control condition to contrast with the effects of introducing route guidance systems into the driving environment. It is generally argued that this control serves as a worst-case, 'no system' condition (Verwey & Janssen, 1988; HUSAT, 1989). Table 2B.2 lists eight studies in which paper maps have been used as control conditions. The table shows the type of paper maps used and the way in which subjects were permitted to use the maps.

Author/s	**Strategies employed by those using map(s)**
Streeter, Vitello & Wonsiewicz (1985)	Customised paper maps in whatever position subjects preferred.
Van Winsum, Van Knippenburg & Brookhuis (1989)	Paper map on a display to side of steering wheel.
Verwey & Janssen (1988)	Subjects memorised a route from a conventional paper map.
Wierwille et al. (1989)	Paper maps (with no highlighted route to follow) in whatever position subjects preferred.
HUSAT (1989)	Paper map on a display to side of steering wheel that could be rotated. The route to take was highlighted.
Pauzié & Marin-Lamellet (1989)	Subjects memorised a route from a conventional paper map.
Schraggen (1990)	Two map conditions were used: a) a memorised conventional paper map, and b) a memorised customised paper map.
Burnett & Joyner (1993)	Subjects presented with paper maps with highlighted route to follow and pen and paper. Allowed to use whatever strategy they felt most comfortable with (notes, maps, combination, etc.)

Table 2B.2 - Review of studies utilising paper maps as control conditions

Table 2B.2 demonstrates how the 'map' control condition has, in reality, varied across studies. For instance, several studies have placed restrictions on subjects' use of maps. Such restrictions have included the types of map(s), the position in which the map(s) were located within the vehicle, the requirement for pre-trip planning, and the required use of memory. It is quite likely that, for many of the subjects within these trials, the strategies imposed upon them were not their preferred methods, and given the choice they would have selected alternative means of navigating.

In contrast with the use of paper maps, there has been some successful use of instructions from the passenger as a control condition (Fastenmeier et al., 1994; Burnett & Joyner, 1997). In this case, it is argued that the control also operates as a 'no system' condition reflecting the ideal situation. Lansdown (1997) employs a similar argument to justify his choice of a car following exercise as a control condition for a simulator study.

Experimental measures

It has been argued by Parkes (1991) that usability evaluations of ITS should incorporate a wide range of measures relevant to the different levels of the driving task. For instance, at the strategic level, observation techniques and surveys are of relevance, whereas verbal protocols, interviews and questionnaires can capture the behaviour of drivers at the tactical level. As noted by Parkes, such an approach provides "complete, rather than partial, pictures of product usability" (p.1445).

In order to provide a wider view of the usability of route guidance systems, reference is made here to the procedural standard ISO 9241 (part 11) - ISO (1997). Although the standard deals specifically with ergonomic requirements for office work with visual display terminals, the document is, arguably, the most formal statement of human factors methodology. Usability is defined in ISO 9241 as a function of effectiveness, efficiency and satisfaction, and these criteria are used in the following sections to group those experimental measures typically employed in the ITS area:

Effectiveness

Effectiveness concerns the achievement, or otherwise of the goals of the user. As stated by Rumar (1993), the primary goal of a driver is to reach a chosen destination*. However, it should be noted there will be secondary aims associated with this overall goal. For instance, a driver may want to reach a destination within a defined time period taking no wrong turnings.

Therefore, important measures of the effectiveness of a route guidance system include navigational errors, and journey time. Both have been commonly used in route guidance research, and have been successful at revealing differences between conditions (Streeter et al., 1985, Färber & Popp, 1991). With respect to navigational errors, there have also been some attempts to add context (e.g. junction and road types, traffic conditions), to provide some understanding as to why and when such errors have taken place (Fastenmeier et al., 1994).

Efficiency

This category includes those measures which have the strongest links with system safety, and therefore has had greatest interest within the literature. There are two sub-elements associated with the efficiency of a route guidance system:

1. Use of resources (i.e. driver workload; attentional demand)

2. Driving errors (e.g. steering wheel variability, use of brakes and indicators, lane changing, traffic violations).

Workload

As pointed out by Verwey (1990), there are no clear definitions of what is meant by the concept 'workload', although the term is frequently used to indicate load on the perceptual, central and output resources. In addition, there are no standardised measures at present, and the concept has been operationalised in a number of different ways. For instance, measures

* It is recognised that some drivers in some situations will make journeys with no particular destination in mind.

have been made of performance on secondary tasks, such as simple arithmetical problems, psycho-physiological measures such as heart rate variability, muscle tension, galvanic skin response etc., and subjective measures. It has been argued that the last of these is the most appropriate for driving related studies, from theoretical as well as ethical and practical points of view (Fairclough, 1991).

One particular subjective workload measure which has been commonly used in route guidance research is the NASA - Task Load Index (TLX). This multidimensional scale (developed by Hart & Staveland, 1988) has the primary advantage that a single composite measure of global mental workload is achieved, which can be explained or diagnosed by ratings given to discrete components. However, the procedure required is lengthy and researchers have reported that the initial paired comparison stage can be difficult to perform with any degree of confidence (Fairclough & Parkes, 1990; Ashby, Fairclough & Parkes, 1991).

The Raw Task Load Index (RTLX) has been demonstrated to be an acceptable, practical alternative (Ashby et al., 1991; Dicks, 1994). This version dispenses with the paired comparison stage, so that subjects rate each of the six factors and an overall mental workload index value is obtained by the simple average of the scale values. Comparisons carried out by Byers, Bittner and Hill (1989) and Fairclough (1991) using the results of a number of studies have found high correlation coefficients between NASA - TLX and NASA - RTLX values and, in addition, have discovered that inter-subject variability was reduced with the RTLX technique.

Attentional Demand

When a route guidance system is introduced into a car, the driver is faced with what Wickens (1980) first referred to as 'resource competition' between the visual demands of the in-vehicle display and the external driving scene. Rockwell (1988) has elaborated on this theme and declared that each in-vehicle display is associated with a 'visual cost' which can be quantified in terms of the number and duration of glances required by the driver in order to obtain information. Parkes (1991) has introduced a third variable for measuring visual demand, glance allocation. This hybrid of glance duration and frequency indicates the percentage of journey time spent glancing towards different areas of the visual scene (e.g. mirrors, road ahead, display), and provides a holistic view of the effect of a particular system on drivers' visual scanning.

There have been a number of discussions in the literature regarding the relative merits of the different visual demand metrics. On the basis of several empirical studies, Rockwell (1988) concludes that glance frequency is the most appropriate measure of visual workload relevant to the in-vehicle display, whereas glance duration is a measure of the influence of the traffic conditions. He also concludes that drivers, although possessing spare visual capacity, are generally resistant to the temptation to look at an in-car display for excessive periods of time. However, other authors have argued that glance duration is important, particularly the number or proportion of excessively long glances (e.g. greater than two seconds) that are made (Parkes, 1991; Lansdown, 1997).

Driving errors

A variety of different measures have been used in route guidance research under this heading. Those which appear to have attracted greatest attention are measures of the lateral position of the car and vehicle speed. With respect to lateral position, measurements have been made of the actual deviation of a vehicle (e.g. Zwahlen, Adams & Debald, 1988), and of steering wheel movements (e.g. Antin, Dingus, Hulse & Wierwille, 1986; Burnett & Joyner, 1993). Both provide an indication of the ability of a driver to stay in their lane whilst using an in-vehicle system, although the latter is a more pragmatic choice for road-based studies.

Average speed has been interpreted in studies as a measure of workload, the hypothesis being that drivers slow down in response to increases in demand (Parkes, 1991). As pointed out by Parkes, there are dangers in such assumptions, since results can be confounded by traffic conditions, and the requirement placed on drivers not to exceed certain speeds. Speed variations have been used to indicate navigational uncertainty on the approach to turnings (Labiale, 1989). The measure is also indicative of high attentional demand, as stated by Green (1995), "when people are given in-vehicle tasks with heavy attentional demands, they tend to slow down to provide themselves with a greater safety margin".

A technique strongly argued for by Zaidel (1991), is to employ an 'expert' rater (e.g. driving instructors) to score the safety of a subject's driving whilst using a system. The primary advantage of this method is that it provides considerable safety-related context to the use of an in-vehicle system. However, as pointed out by Zaidel, there are issues regarding the reliability of judgements made by experts, and the extent to which subjects' driving behaviour is influenced by the presence of the expert.

Unfortunately, to date, there have been relatively few uses of expert raters in the route guidance research field. Oxley and Mitchell (1995), Pohlmann and Traenkle (1994), Fastenmeier et al. (1994), and Zaidel and Noy (1997) were the few which were revealed by this literature review. Recently, Zaidel and Noy (1997) have proposed a common methodology for using an expert rater. They define a Quality of Driving (QOD) index which comprises eight dimensions of driving. An expert observer (in their case, an advanced driving trainer) rates subjects' driving on each of the dimensions (a 1-9 scale) at various times during the journey. The development and validation of this scale (as described in the paper) may mean that future route guidance research makes greater use of expert raters.

Satisfaction

Satisfaction is an important element of usability, and techniques such as questionnaires and interviews have been commonly used in the literature to measure it. These methods allow the investigator to assess drivers' recent experiences during the trials, together with their general knowledge (Parkes, 1991).

A problem with this dimension is that of novelty. Many studies in this area have used prototype/commercial systems, and it is likely that few of the subjects had seen a route guidance device before, or were even aware of the existence of such systems. To a certain extent, this perspective helps to explain why, in so many studies, strongly positive views have been expressed by subjects (e.g. Oxley & Mitchell, 1995; Burnett & Joyner, 1997). Undoubtedly, drivers will become more discerning in their opinions, so that novelty will become less of an issue, as awareness of the technology rises across the general population.

Ease of learning

In addition to the above, there are measures which concern temporal aspects of usability, and which cross over the three ISO 9241 criteria. The term 'ease of learning' has been used in the literature (Nielson, 1993) to group these. According to Nielson, there are two aspects to this dimension of system usability: learnability, i.e. the length of time it takes to reach an 'expert' level of performance; and memorability, i.e. how quickly users can return to being an 'expert' after time away from using the system. Both are important for assessing the requirements for training with respect to a particular interface style.

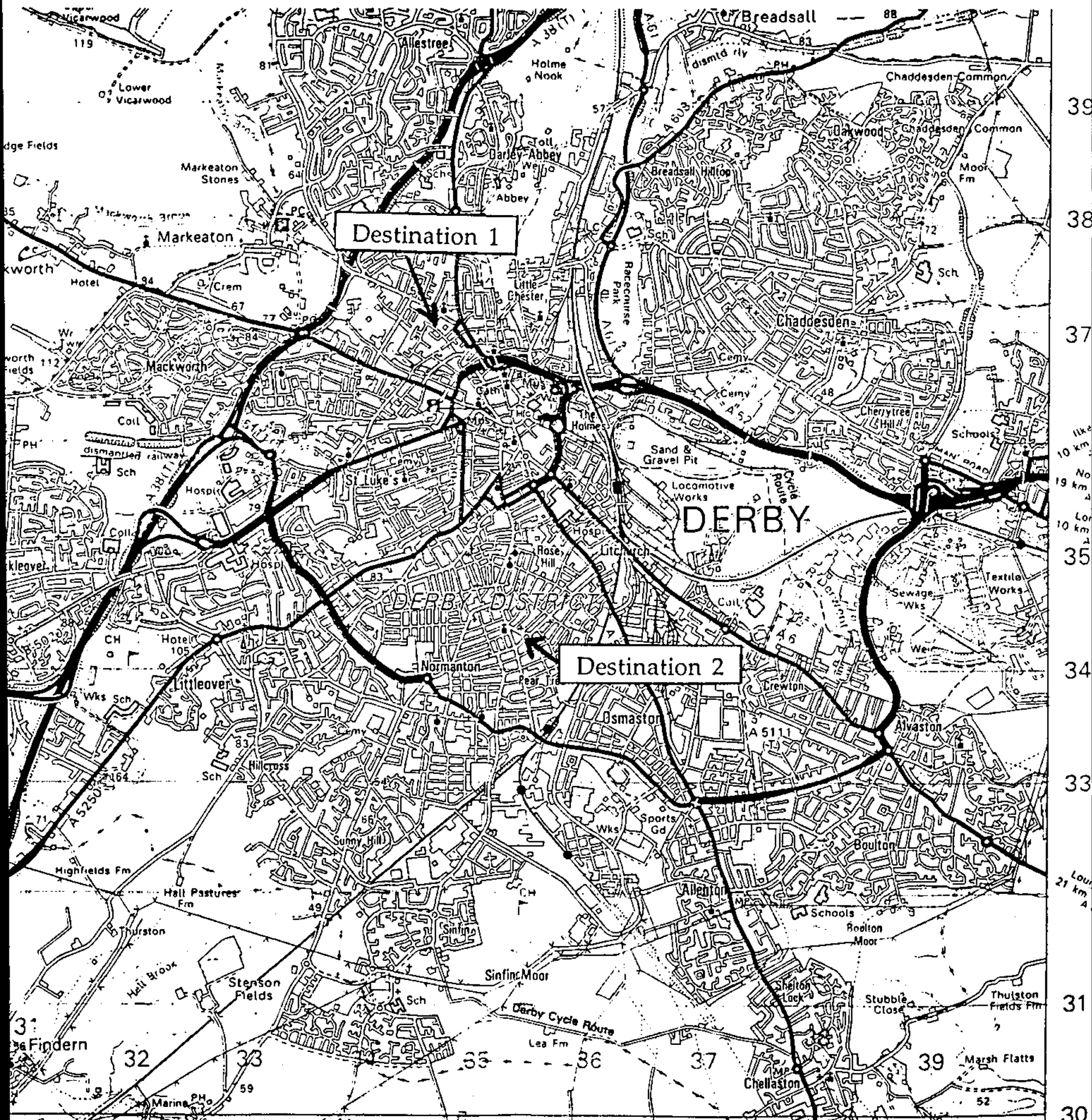
With respect to learnability, there appear to have been no attempts to measure this dimension of usability for a route guidance system. Few studies have quoted the level of training that was given in relation to the use of the route guidance system (notable exceptions include Green et al., 1993b; Kishi & Suigara, 1993; and Burnett & Joyner, 1997), and there has been a general assumption that an expert level of performance can be reached with as little as an hour of system training. In certain studies, there appears to have been either no training (e.g.

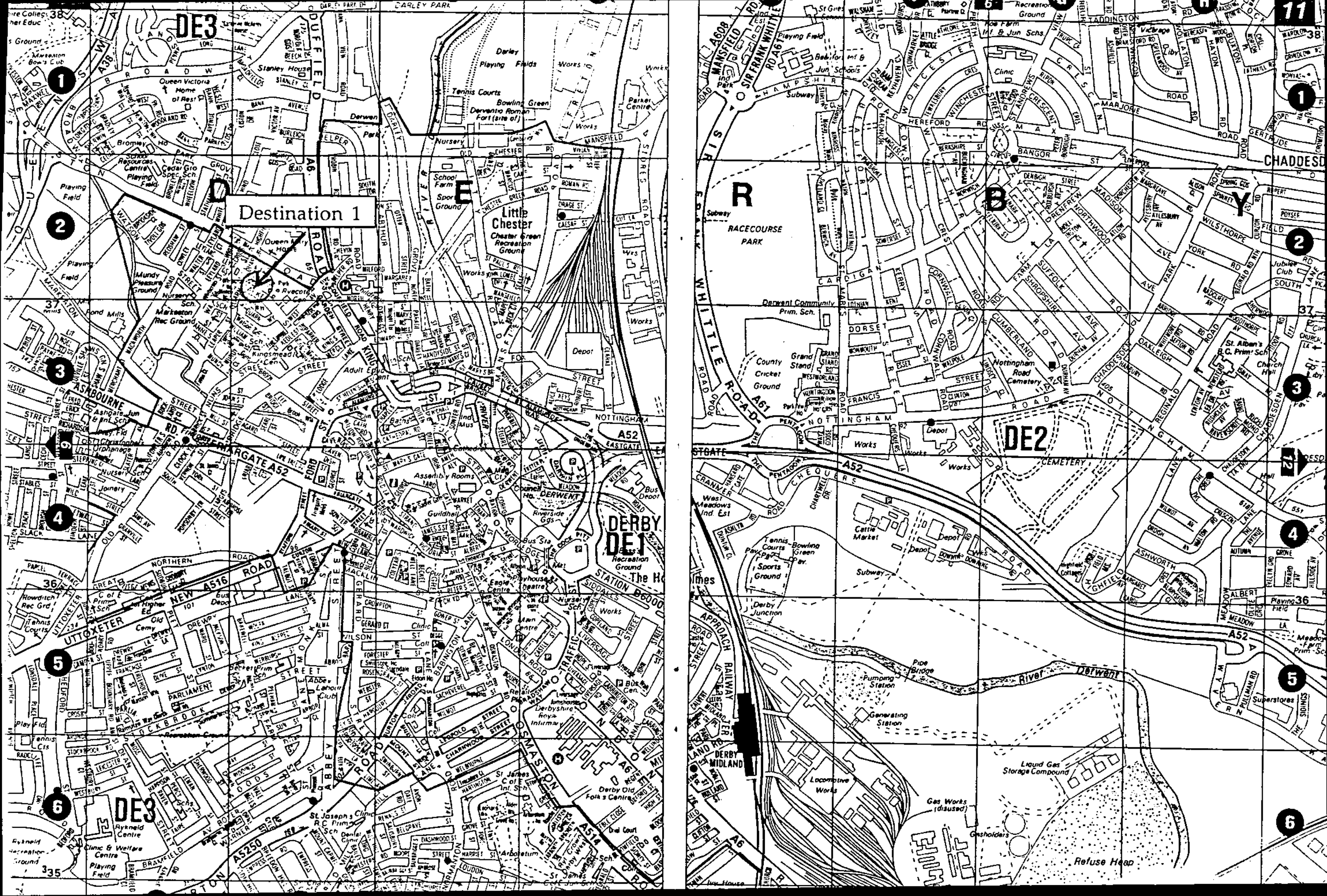
Obata, Daimon & Kawashimo, 1993) or just a few minutes worth of driving and using the system (e.g. Verwey & Janssen, 1988).

There have now been some longitudinal studies in this area (e.g. Foley & Hudak, 1996; Dingus et al., 1997). However, the usability dimension of memorability appears not to have been addressed by these researchers, despite the implications of the measure for occasional users of a system (e.g. rental car users, or those who make unfamiliar journeys once a year on their holidays).

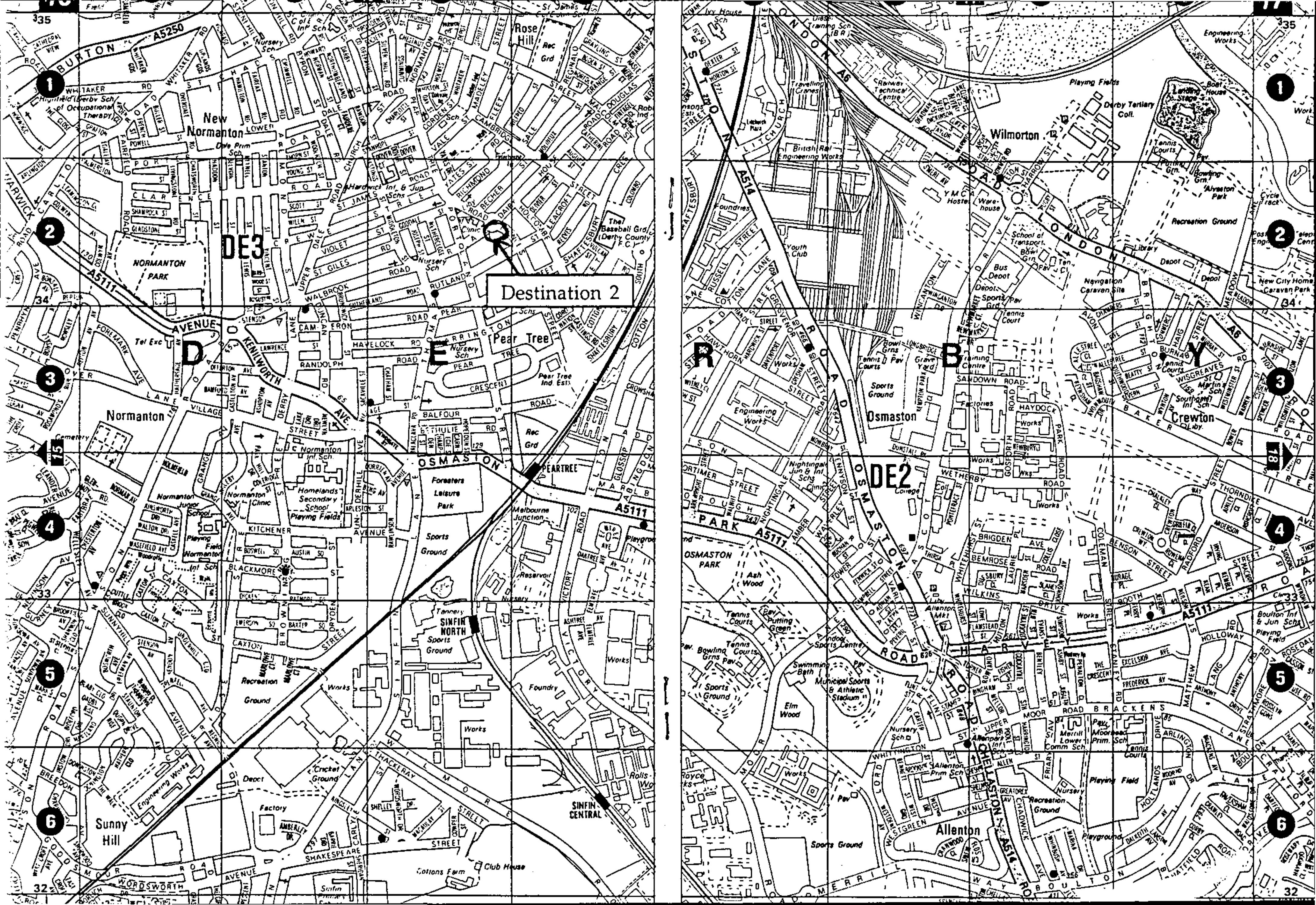
APPENDIX 3A

Maps of test area for road trial





Destination 1
DERBY
DE1
DE2
DE3
DE3
11
12
9
Little Chester
Racecourse Park
Darley Playing Fields
Derby Midland
Assembly Rooms
Guildhall
Cathedral
Council Ho.
Derbyshire Royal Infirmary
Cattle Market
Nottingham Road Cemetery
County Cricket Ground
Locomotive Works
Liquid Gas Storage Compound
Gas Works (disused)
Refuse Heap
River Derwent
CHADDESDEN
NEW A516 ROAD
FRIARGATE A52
DUFFIELD ROAD
SIR FRANK WHITTLE ROAD A61
NOTTINGHAM ROAD
UTTOXETER
ABBEY STREET
OSMASTON



Destination 2
DE3
DE2
D
E
R
B
Y
New Normanton
Normanton
Pear Tree
Sunny Hill
Rose Hill
Osmaston
Crewton
Allenton
Wilmorton
NORMANTON PARK
OSMASTON PARK
Foresters Leisure Park
SINFIN NORTH
SINFIN CENTRAL
PEARTREE
Melbourne Junction
A5111
A5250
A514
A6
BURTON
KENILWORTH AVE
OSMASTON ROAD
LONDON ROAD
HARVEY ROAD
Derby Tertiary Coll.
Recreation Ground
Sports Ground
Cotton Farm
Club House
15
18

APPENDIX 3B

Transcripts of interviews with drivers

Subject 1 - Route 1
Overall plan - Very little planning beforehand. Generally, planning to follow signs for the A52 and when got near town (looking for built up area and signs for town centre) was going to stop and look at map. Took the correct turning off the Pentagon - but didn't really know where he was - just wanted to get into town and then stop and plan route. In the wrong lane coming off Pentagon and got shunted off to the left. Realised mistake and aimed to get back onto A52. Round roundabout (cockpit) and back Wanted to stop and look at map (unsure where to go), but nowhere to stop (dual c/way) - failure of plan. Then saw sign for town centre and thought a) would be able to stop and b) destination was near town centre. Went into Queens st - basically looking for somewhere to stop - turned into St michaels. At this stage "I had no idea where I was". Re planned when stopped. Used a church to help orientate himself, ie didn't know which direction he was facing.

Was now going to get to destination via memorised step-by-step instructions (combination of street names and counting turnings). Successful for first part (onto 1-way - realised that 1-way from map) - got him close to destination. Wanted to take 1st left after 1-way system. Not clear of side turn and missed it (did not see st name), so went on and turned around further up. Kedleston rd was quite a fast road and a) difficult to stop b) difficult to see the st names especially at speed, plus c) not clear both from map and when driving whether rds to side were dead end or not. "Perhaps, I did not look at the map close enough beforehand". Came back stopped a few times to check where and then turned into Quarry st. Thought from map that could get into Elms st from there, but couldn't so then swept back and into Elms, but was dead end (not clear from map). So confused and frustrated at this point looked at map again - worked out could approach it from a different angle - went around 1-way system (had already been on it so knew where to go and turn onto West ave along Parker st and to Pub - looking for st names throughout.

Subject 1 - Route 2
Overall plan - Difficult at beginning because so many dead ends. Wasn't "keen on the town centre" so was aiming to go out of town and back in to destination. Wanted to turn right and then left onto Uttoxemeter, but no right turn so went left, right, right and then left onto Uttoxmeter. Was essentially just doing lefts and rights to get across to the A516. Knew was on it, because it was a main rd. Felt it was a bit time consuming to go through residential roads. Originally thought of going across, but once on the road realised that it would be easier to go around . Looked for rd signs for A5111. Then had it in mind to stay on road for "a while". Knew had to go over a roundabout - in retrospect feels it would be better to go left at roundabout and then straight to destination, but didn't look at the map enough to realise this. General statement - "do this all time - I don't get a clear idea in head where going - just a rough idea of generally where heading". Would turn left some time after that and stop and work out exactly where was and then follow map to destination. Wasn't quite sure how far to go down road.

A5111 was fast and difficult to see st names when travelling at speed. Also difficult to stop on the road. Decided to just make left and then stop. Turned into Eugene and stopped to work out where. Was counting junctions along Portland st to find Walbrook rd, but miscounted and turned too early. Very confused around this area - couldn't find street names - knew was close, but couldn't quite get there, and drove around until found it. What would you do differently? - plan it more - look at map more carefully before started - although feels that it may not have helped, since so difficult to know how city roads will actually look from map. On the whole felt it went quite well - but wanted to stop on roads, but couldn't.

Subject 2 - Route 1
Overall plan - Focusing on the inner ring road (based on quick look beforehand) - wanted to stay on the A52 and flow round to the right and at some point drop down onto the residential streets to the right. Knew was on the A52 based on quick look at maps after motorway. Established that would have to go straight across at one roundabout and then there would be a more complex roundabout where wanted to flow to the right.

However, thought had gone over first roundabout (crossing A6005) and at second saw road sign for ring road (actually outer not inner) - so he took it and exited A52 thinking it would then flow to the right. ie felt was much further up the road. was a "bit surprised when it flowed to the left". " I cocked up!" Almost immediately realised that made mistake - didn't look like town centre - expecting to see inner ring road traffic and conditions - but the road was dual c/way with little traffic and lots of factories (don't usually see these in city centres). Couldn't turn around or stop - had choice could wait and turn around - there was a roundabout where he could turn - but he realised via road signs that he was on outer ring road. Then saw road sign for city centre and decided to take that - already knew (from looking beforehand) that A6 went onto inner ring road - plus Loughbough people know that A6 London road goes into Derby.

First scan used to get bearings (ie the arrangement of the main roads going into Derby). So in planning first looked at st map to see where Parker and Elm were, then had quick scan of Atlas to see what the different roads going into Derby were. Mentions that happened to know that Derby had inner ring road, but feels that would have made that assumption for any city if roads looked as they did on map. Along A6 just following signs for city centre. Originally, based on looking at map, was aiming for inner ring road. But noted that could cut off to get to ring road further up - feels that it was primarily the colour of the road on the A-Z (yellow) that made him decide to take this alternative route - felt there must be a good reason why it was clearly shown on map (ie congestion further up the A6). Had also noted that the station was along the alternative route - so followed signs for station ("knew it would be signposted"), plus signs for inner ring road. Not using number/name of road - difficult to see name (across fold on map).

Got to cockpit and wanted to flow off to the right and onto to original plan (ie along A52 and off to the right at some stage). However, missed the turnoff for A6. Did not see a road sign, and had "in minds eye that I needed to go right, not left". Almost went left, but was unsure and decided at last minute to continue in current lane which took him further round ring road. With complexity of road layout didn't know that would have to go to the left first. Was expecting to get shifted over to the right and onto Duffield road, but wasn't - realised mistake at stafford street - still looking to turn right at this stage, and looking for Duffield road, but then started feel uncomfortable that had travelled too far.

Quick look at map and saw Friargate and then positive that had gone wrong. Stopped to replan in stafford st. Looking to get back to inner ring road at this stage - was in a maze of small streets and very unsure of location - "could have cruised around for hours" - very unsure of where exactly he drove before ended up on Bridge st. "Got into a mess and ended up on Friargate turning onto Bridge st" -still aiming at this stage to head roughly northerly direction and onto Ring road. Realised when on Bridge st (stopped since essentially lost) that very close to destination ("could almost drive around and would get there eventually") and could get to destination via residential streets and didn't have to get back onto ring road. Worked most on premise that it was a few lefts (3) in succession and then would be into Parker st. Had also noted from map that Elm st would be deadend. Was also looking for st names.

Subject 2 - Route 2
Overall plan - Before set off checked st map and also larger scale map (on A-Z) to see precisely where needed to head. Looking to establish overall view before setting off. Two critical points picked up on - London road A6 and DRI hospital - was aiming to head back around the ring road (clockwise) towards these points. Wanted to go straight onto ring road - made slight error of judgement by not turning around and heading back -went longer and around houses - was in mess, attempting to go round block (in circle to get back) - realised that could carry on up Brook st and onto ring road - but truck in road reversing so made quick decision to turn left onto Bridge st (had already been up here so knew rd) and then went round one-way. Saw rd sign for inner ring rd and dropped off to the left onto ring road.

Then aiming to stay on the ring road and turn off on A514. Knew that hospital would be signposted and had Omaston rd, A514 in mind as well. Off the A514 knew had to turn off at some stage - wasn't quite sure where. Picked up Lenord st as went along road. Realised that had boys names for sts - so must be pretty close. Saw that couldn't turn down Abaroreth - stopped a few times to check where he was on A514 - realised needed to turn down Reginald - hadn't seen Douglas (on fold) - stopped down Reginald to plan final part, but made mistake. Was going to continue until end of Reginald and then turn left at end of road and then 2nd right, but turned too early. Mentions that not using so much street names at this point.

Why turned early - hadn't noticed when looking at map beforehand that Reginald turned into Sale - and so when got to end of Reginald and saw Sale ahead thought must have misread map and wasn't T-junction aiming for after all. Realised had made mistake when stopped to get onto Malcom st. Then knew by taking a right turn was heading in right direction, but was not sure if on right road so stopped and looked at map - saw Catherine st on side and then realised exactly where he was and continued along road until saw pub. Hadn't realised that at roundabout - just continued - confident that would see it.

Subject 3 - Route 1
Overall plan - aim was to get onto ring road - looking for A6 signs to turn off heading northwards. Kept right after pentagon - didn't see road sign for A6 as travelled along A52 - suspected had made mistake, and wanted to turn off to establish where he was - turned off towards town and stopped. used st name to locate himself and replanned route.

Decided to go through residential areas to destination - less hassle than ring road. Original intention was to turn up Keddleston gdns which then intersected with Parker, but although could go into Ked gdns couldn't get through far enough for Parker. So reversed and replanned again. Just looking for st signs to find these turnings. Didn't count streets in this area - difficult to count so many turnings around area.

Subject 3 - Route 2
Overall plan - realised that crossed to two pages so looked at overall map at front to establish connection. Weighed up possibility of going around ring road vs a more direct route through city centre. Went for 2nd feeling it was still "quite clean". Looking to get towards Abbey st which he had noticed linked A516 and A5250. Although also saying that aiming for Wardwick and Victoria - more direct route. Notes that was impossible due to 1-way system.

Initially worked off memory to get to St Nuns st and then turned left towards Friargate. Saw that it was bigger road and A52. Went left - because couldn't go straight on - then looked to stop ASAP and replan. Drove for a while before was able. Generally looking to get across to A514 which he knew he could then turn off for Pear Tree. Not sure of the streets that he drove in - knows that eventually he picked up Abbey st which he knew from original plan would lead to area wanted to go to. Just working off st names to get through - not picking out any landmarks. Very unsure of how got there. Remembers last bit of this drive. Trying to escape from city centre in a roughly southerly direction. Very difficult to stop in central area so just kept going until could stop and replan (where realised Abbey road cut through) Had spotted signs for Eagle centre whilst in central area (I think he's been there beforehand).

Plan from Abbey road was to turn onto A5250 and then onto Omaston rd A514 - if all else failed would turn onto A6 loughborough. So following signs for A514. There are roundabouts which do not appear to be marked on map. Knew was coming out of city centre once on A514 - decided to just continue until could find convenient place to stop along road and establish turning off. First point was a long way down - but road was fast - so not far in driving terms. Stopped at petrol station. Replanned and counted streets to establish Douglas - noted that it was the turning after Shaftesbury. Not sure if counted all (just take Douglas - one after Shaftsbery) Turned onto Douglas successfully - knew that should be able to see pub as road turned into Walbrook - hadn't noticed that was at a roundabout. Not looking for anything else - fairly confident that would find it eventually - mentions that would have felt worried if had driven for a few miles and not seen anything.

Subject 4 - Route 1
Overall plan - aim was to go around ring road and to turn onto Duffield road- also knew it (I think he means the Kedleston turning) was on the A6. When got to Pentagon saw road signs saying A6 Matlock and tuned right. Thought he was at A6 junction (further along) - mentions that he has been to Pentagon before when travelling to Belper (is on A6 and after Duffield) - says after probably been there twice in last 30 yrs, but has never been to bit further in. Previous experience affecting judgement. "I was stupid" - knew it would go to A6 - feels that did not spend enough time planning beforehand to establish exactly where to turn. Having been down this road beforehand saw Duffield road A6 on map and that Keddleston was just off it and thought "I know where I'm going here". Also knew that A6 went to Duffield and wanted to turn off Duffield road so was sure that doing the right thing.

Actually kept following signs to get onto A6 (seems to be little awareness of where travelling in space) - unaware of signs saying A38 - just saw A6 and knew had to be there. Feels should have realised that previously he had been on outer ring and not inner ring. When did realise make mistake? - much further up - kept going thinking the turning he wanted (left onto Keddleston) must be somewhere along A6 - nearly got to Duffield "I can't believe this" thought he must have missed it - so turned around and on way back stopped someone and asked them (from video I think he showed them map) - they said he needed to keep going for quite a while back into town (seems he didn't even know where he was on map - "sure it was going to be just after the roundabout" - ie after the right onto A6). Went all the way round 1-way system but did not turn onto Keddleston - says that Ked looks bigger on map - actually another one as big (actually not on map - between Duffield and Ked) and turned onto this one - "someone (passer by earlier on) said Keddleston would be just before you come back round to Duffield" - had also noticed from his own map that roads were 1-way so could go round. Did not see street sign for Ked.

Bit hazy about what did in residential roads after that - thought was very close - someone said was wrong - couldn't believe it. - then all over the place - couldn't get through to Parker - asking lots of people (about 15) - lot of them were students on 1st day and didn't know anything -asking about pub and Parker st. - 2 woman refused to speak to him - thought he was trying to pick them up! - looking for people who looked like locals - but couldn't see anyone. Feels he almost stumbled across pub in the end - feels that he would have found it easier with overall view instead of pages on map - very angry with himself for making first mistake and felt might have influenced judgement later.

Subject 4 - Route 2
Overall plan - Thought that he might see a sign saying Peartree - also thought he might see signs saying A514 - nearest main road to destination - but as far as he could see "A514 doesn't exist on any of the signs" So actually planning to get across to A514 and turn off on Douglas and follow to destination. First planning to get onto 1-way system - and then planning to "get south". "because I could see no way of joining two maps (2 pages?) thought as long as see road signs for A514 ok". but no signs.

Therefore, just kept driving in what he hoped was a roughly southerly direction until he could find sign saying A514 - thinks he ended up on A516 -can't remember if he stopped or not. Decided to go on A5111 from looking at his own map (when parked up along A516) and realising that A5111 skirted the bottom of Pear tree - (seems he wasn't very sure of his direction of travel here) - thought he had gone wrong somewhere since he had found himself in areas of Derby he didn't like the look of (ie not towny enough and signs that pointed to towns he knew were way out of the city). So turned onto A511. Along A5111 stopped and realised that could turn at "first major" roundabout left onto Stenson - got to 1st roundabout and "risked it" - pulled left even though didn't see st name - then stopped and asked someone "do you know where Stenson st is?" - answer "you're on it" - then asked where Walbrook st was - told to carry on and would flow into Walbrook - couldn't see st sign for Walbrook from where he was, but could see junction and road to take - then just carried on to roundabout (knew it would be at this junction from looking when at Stenson) to pub. Summing up -should have done more planning before both routes (especially 1st) - "too cocky"

Subject 5 - Route 1
Overall plan - quick look to find destination on A-Z - realised that needed to get to 1-way system off ring road - following A52 follow signs for A6 (knew it wasn't A6 to loughborough) - realised Matlock was also in this direction. Followed signs for A6 at pentagon - took me straight on - moved over to right hand lane following road signs for A6 and city centre.

Then came off ring road (although it seems he hadn't realised this) and towards A6 - unsure whether he realised that he was heading towards the A6, because he then turned off left following sign (he thinks) that said inner ring road. Reason - knew had to go left at some stage and thought this was the turning for 1-way system. Then realised had made mistake (felt he was going back into city centre and knew didn't want to) and decided if took side turn could stop and establish where he was. - stopped along Lodge st and saw sign for Bridge st and then used A-Z map to locate. Decided to come in the back way through residential streets - easier to stop and not having to make decisions quickly. Looking for street names and stopping to check that passing the right streets along the final stage of route. Pointed out that need to check street names a lot because sometimes kids can change street signs around. Not counting streets at all - just looking for ones as passing.

Subject 5 - R2
Overall plan - aimed to find A514 - Omaston rd from going clockwise around ring road, and turn off Douglas st - had noted Derby royal Infirmary as near A514. Looked at A-Z and lined up in head the two pages.

To get to ring road turned up West ave and onto 1-way system (1st left) - from 1-way system - "I'm going to have problems telling you where I went - I could not do it again" - got ring roads confused -

as heading along 1-way just aiming to follow signs for inner ring road. Ended up going wrong way around ring road - realised mistake instantly (going wrong way) and came off into town hoping to go back the other way (ie clockwise). Drove around a while (couldn't stop or look at maps) until able to get back onto ring road the right way (passed a lot of no entry roads, making more difficult) - following signs for inner ring road at this stage. Kept seeing signs for A52, A6 and A516, but not A514. Therefore, decided to follow signs for A6 Loughborough (knew it was close to A514 from looking beforehand). However, felt by this time that better to go into city centre since was being taken by the flow of the traffic on ring road (also limited exits, so can get taken right out of your way) - feel that would be able/have more opportunities to slow down and/or stop and establish a landmark, street name in the city or ask someone (didn't though).

"Little bit of I know I'm going in the right general direction" - and then went past Assembly rooms (know it is where they play snooker - although never been there) - saw it on map and so knew that was doing the right thing. Saw road sign for A6 Loughborough at a roundabout and then followed that - also saw lots of buses and after looking at map realised that passing bus station. Also saw signs for Assembly rooms and bus station before actually saw them. These landmarks were "more of a reassurance really". Turned right at cockpit roundabout using road signs for A6 Loughborough - when in queue at next roundabout saw street name - Bradshaw way in front of him and then was sure that just had to turn left at next roundabout (onto Osmaston road). Kept Hospital ("Derby Royal") on left whilst travelling along A514 ("just for extra reassurance") - travelling slowly on this road - not very many major side roads before Douglas road - would normally have noted other streets from map as going along (at least 1 or 2 of the roads before actual) but was expecting Douglas to be further down - Why does this - allows you to prepare so don't suddenly "end up on top of junction".

Spotted Douglas as it is on a roundabout - was in the inner lane expecting to go straight on but saw Douglas and had to change lane late to make it. Plan now to go along Douglas looking left and right until saw pub - knew it was on a roundabout (from looking beforehand) also looking for Walbrook road - checked name on instructions as went along.

Subject 6 - Route 1

Overall plan - head for the A6 Matlock from A52 (involving going along what thought might be a ring road (noted that discontinuous and looked confusing). Saw roundabout (five lanes) along A6 - looked quite easy - ("a left and then a right").

Made note that had gone through Spondon along A52. Had not noted the Pentagon roundabout beforehand - "looks obvious now - thought it would be simpler" - made mistake at this junction - saw signs for A6 Matlock at this point and so went right - realised mistake a while up road - "doesn't look like city centre - too empty - expecting lots of traffic" - then saw sign with A6 in further brackets and "something about road sign made me realise that on bypass - obvious really". - so stopped and checked map to see what had done and turned around. - thought easier to go back to original plan. - knew should have gone straight over first roundabout.

Once on A52 was going to follow it until saw another sign that said A6 Matlock. General note - didn't realise that Derby was so small (thought it would be Nottingham sized) and didn't get a feel for it when looking at map beforehand. Went over flyover (which though beforehand was a roundabout) and saw signs in time to take him off for A6 Matlock. However, because felt turning off A6 would be further along (plus thought five lanes r/bout would be bigger) went past - realised had made mistake at next roundabout (didn't see sign for West ave on left?) and continued to next r/bout to turn around - stopped there and checked map - interpolated distance from map this time to be sure of where roundabout would be (1.5 km, approx. 3 mins driving). Also had feeling that it was at the 1-way system that turning was. So continued to 1-way system and decided to cut across (Keddleston gdns) - firstly, turned into North st to stop (easy to stop here) and turn around and check - felt that continuing on 1-way system was taking him away from where wanted to go and might get lost trying to find way around it. Could see sign for Keddleston from North and saw it on map so knew exactly where was - didn't look for anything else in this area.

Note that thought about possibility of going down A38 from when stopped on A61, but thought could be too complicated. On his map thought he would be able to turn off onto Kedleston rd (on Maxwell av). However, his map has a circle with 1 on it over junction (ie it is on page break) and actually this manoeuvre is impossible.

Subject 6 - Route 2
Overall plan - originally thought about using straight route that went through centre, but decided against - the problems of roads that look continuous in reality are not (in city centre). Decided to go back around ring road over a couple of roundabouts until got to A514 (wrote this down so wouldn't forget -had noted that also Omaston) (just after A6 turning - "well marked always"). Then would be several turnings later would reach Douglas rd and follow this to pub. notes that finds it hard to remember names so doesn't make detailed plan.

Started off going back the way came working from memory. Got past 1-way system - thought would be clearly signposted A52 Nottingham/ring rd after this and A6 Loughborough after this. However, got himself in wrong lane (expecting it to be further along) so went straight on instead - realised mistake immediately. Then went into city centre on Queens (used map to realise where was) - had decided to follow original plan (ie weave through centre) - went around for a bit and felt that was going away from central area - also "didn't like the look of the city much!" (lots of pedestrians, traffic and a lot of it was 1-way, bus lanes etc.) - then saw sign for A52 at roundabout and changed plan again back.

However, could only go back onto A52 in wrong direction - realised that not Nottingham direction too late (wasn't sure where Ashbourne was). Decided to get back off as soon as possible or turn around - came off at the same point going back into city centre (ie change of plan again!) - stopped and looked at map along James st (not sure) - had driven blind for a while just aiming to go in generally right direction - plus when had driven there beforehand had felt that Full st was wrong route (too far off to the left - not quite in the right direction) so had taken other turning as came off A52. Notes that is was going to Derby again would make note of Parking places - very large and prominent as driving through. Would also have noted Hospital (very big as passed it later) - notes that don't know how prominent they are from map. Located himself from James st name on wall. Then plan was to get around to cockpit - turned around in a car park. Noted that had to go across to a roundabout and turn right - across the next and then would reach big roundabout (cockpit) - nothing else - felt that would be simple.

Then looked for signposting for A514/A6 -as approached A6 saw that lane was marked A514 this lane only so was sure doing right thing - "finally, felt happy". Didn't see Omaston - "wasn't even looking for it anymore - didn't need to - A514 was the important info and all the info I needed". Final stage - wanted to take a turning off to the right - had written down Douglas but wasn't looking at it and had forgotten name. Knew from the beginning that it was more than about 5 turnings down anyway. Saw St reginalds and took it (not sure). - was quite a prominent road compared to others which were looked small or dead end (had its own slip rd). Had also seen that there was an American st pattern to Pear Tree area (linear network of roads). This meant that he knew from the beginning that he could take any side turn and it would be very easy to navigate around area (so not worried about it). Stopped on Reginald - knew had to take left (noted that at end of road) and then right (not sure if saw it as 2nd or not) onto Dairy House rd. Then follow rd until reached pub. didn't see it as on r/bout - just a short distance.

Subject 7 - Route 1
Overall plan - mentions that knows roads up to Pentagon - was going to go to there along A52 and felt that A52 would merge into A6 later on - was then going to keep going up to the 5 lanes r/bout and turn off onto West Av. To start with followed the A52 and followed signs that said A52 Derby up until Pentagon - then nearly 'threw a wobbler" - saw signs for A6 at that junction and for a brief moment thought that had gone too far up the A52 (ie was at the A6 junction) or had originally misread map. Was in the wrong lane to get across anyway, but feels that did not turn right because was not far enough into the town (did not look like city centre, plus knew that the A6 was on the North side of town). Also knew had to go through what was likely to be a congested part of Derby and roads were quite clear where he was.

Then aiming to pick up A6 signs, but mentions that not clearly marked until quite late - feels that took the right turning (off to the left) partly as an accident - happened to be in the correct lane - "mentally I felt that I needed to go right not left". Did see a sign on the gantry though. Mentions that generally will navigate in an unknown area by a process of getting in the right area first and then will stop in quieter roads to establish last part of journey. Followed flow of traffic coming off A52 looking for somewhere to turn off and stop. Because of twists and turns (ie 1-way system) unsure as to whether still on A6. "At this point I had no idea of where I was". Pulled into side turn just to get off the flow and found himself in West Ave (ie where he wanted to be!). Spotted the st name and couldn't believe it. Then turned right at the end of the road and followed to pub.

Subject 7 - Route 2
Overall plan - knew had to go back through the centre. Knew the hospital as has driven past it on way to Eagle Centre (some years ago). Knew it was between A6 and A514 (from map). Aiming for A514 (saw that was close to A6) and getting onto inner city ring road clockwise to get there. Therefore, on signs was aiming for city centre (first) followed by A6 and then A514. I think he felt (based on a view of a road sign earlier?) that if he followed rd signs for city centre he would also be lead around the ring road.

Went back the way came to get onto 1-way system. Then followed signs for city centre (had passed signs for centre as came off A52). Not quite sure what did - "got a little bit confused and lost my orientation" - was filtered off back onto ring road going wrong way. Don't remember seeing a sign for ring road. Saw sign for city centre and then went into high street type driving. Was disorientated at this stage and driving 'blind' to start with. Remember passing the Eagle centre later on. Wasn't concerned that uncertain - worked on the premise that most major trunk roads coming out of city will be well signposted. Wasn't looking for street names as moving through centre. "traffic moving too fast" - fact that passed Eagle centre surprised him - didn't think he was going through centre. Seeing Eagle centre helped made him sure that he was coming out of city centre and on the right side too. Doesn't remember seeing road signs for A514 until reached cockpit - saw signs for A6 loughborough quite early in the centre.

Turned right at cockpit following signs for A6 and A514 and went straight ahead at next roundabout. Then found himself in wrong lane (outside) - feels that A514 came up on him too quickly and so had to cut across 2 lanes. Looked at map when come off A514 to plan last stage. Mentions that doesn't look at maps much when moving - feels he is a confident driver, but fast and when concentrating on road signs (which he feels can be poor) difficult to look at map too. Aiming for Douglas rd as straight through to destination. Only looking for st name (notes that would normally note one before as well, but this time did not) and wasn't counting along road ("too many"). Wanted to turn off right - wasn't too concerned really as to which one - knew that could get there with any - Reginald seemed a good choice (fairly decent wide road). Mentions that has poor comprehension of distances - wasn't using it to judge where to turn. Also mentions that stuck behind milk float so happy to turn off early. Saw st name once committed (two lanes -was in right)

Had problems with distance along Reginald (different speeds) - plan was to go to end of road and turn left. Thought was at end when got to cross roads with Sale - then saw Sale st and realised had to go further (knew that st name would change - initially thought it already had). Looking at map at this stage - noted that 2nd right onto Dairly House. Then followed road to see pub - saw it from the junction.

Subject 8 - Route 1
Overall plan - looked at A-Z to see where roads were. Aimed to follow A52 until got to town centre. Then bear over to right until road splits where would turn left. Since plan was no more than that had in mind to stop as soon as possible once into town (somewhere around the junction with A6).

Knew Pentagon and that should go straight over to continue on A52. Didn't know any more - could see that was complicated and needed to stay on A52. Was looking for A6 after Pentagon (was looking to stop as soon as had established that junction). Went too far and past the A6 (saw signs but in wrong lane and couldn't get across - had in mind that had to go right not left). Didn't realise mistake until got to A52/Friargate junction (why? "no more signs for the A6 for a start". Also saw Ashbourne rd which had seen before set off and knew was past turning.

Turned up A52 Ashbourne - realised that was not too far from destination and could get to via the residential streets - was then aiming to get across to the right. Tried to turn up one of the side streets (bridge st he thinks), but saw that couldn't (no entry) and had to continue on and turn around. Meant to turn up Nun st on way back, but didn't see st name ("missed it") - probably because Brick st to start with! so went into next (bridge st). Knew it would do him just the same. Then just followed st names until got to destination. Wanted to go up Keddleston, but bollards in way (couldn't see this from map) so went around. Was also counting streets within this area. - didn't note any landmarks during drive.

Subject 8 - Route 2
Overall plan - needed big map to get overall view of where destination was in relation to current position. Thought that would have to head in a roughly southerly direction. Big map didn't help - established relative positions via turning over different pages on A-Z.

Feels should have gone back way came to get to A52 (Friargate). but didn't. All I was interested in was getting down in general direction towards destination and then stopping. Wanted to get to A516 and then across residential roads to A5250. Wasn't interested in using ring road (problems from first route). Also, didn't have the overall view seen in front of him now and feels that may have gone a different way if had seen more clear view of where destination was before set off. Thought also that A516 and A5250 were bound to be signposted so "just set off really". As came out from West Ave "road just swerved off to the left" - in wrong lane - knew didn't want to go left but continued. "Should of stopped really" but kept going. Also, knew that right was 1-way taking him to city centre and didn't want to go there (hadn't interpreted this road layout beforehand) - so decided to continue.

Had in mind to turn left at some stage along road and left again to get back in right general direction. Thought about turning earlier but by time saw st name was by it. Saw Markeaton park at time, but only notes it now - didn't make the connection properly between pages it seems. since realises now that would have been best to continue to A5111. Knew A52 city centre was back in the right direction so went up it. Stopped along A52 and looked for Uttoxmeter. Also took on board some of the other roads that was getting close. Saw sign and knew had made correct turning. On his map at bottom of Uttoxmeter is big circle which obscures junction with A516 (and road on other side of road). Knew had to go across and get onto Bedford. Because that was not the road ahead of him decided to go right and then first left - this too was not Bedford and was dead end so went back and took the turning whose name was obscured by the dot.

Along Bedford knew had to turn along Westbury (4th left) - then it was right at the end and then left at the end (didn't note st names along here - confident that wouldn't need them). Essentially weaving across to A5250 here. Was planning from here to get to A5250 to take first right, left at the end and then first right which would take him to main road. However, couldn't get onto the A5250 from last road (line on map, but have to look very closely). So went back and right at end and right at end onto Abbey rd (noticed st name for Abbey - biggish road with prominent st name). Abbey rd took him to main road - the A5250 where turned left. At this stage was looking to get onto Nomanton which he had noted was a long road straight through to destination (not sure which one he took to get there). Was originally going to go down Lime Ave (1st left), but had noted all 3 of the turnings and knew could go down any of them. Passes Lime before could realise so went up next and then left at end and right onto biggish road (Normanton).

Knew at this stage didn't want to come off this road. Looked at a few of the street names along the road to check how close he was (Saw that passed Rose Hill and could see from map that roughly same distance and would get there). Also noted Yates and when saw it knew was close. Didn't notice any of the churches. didn't count the streets along here - too many. Hadn't noticed that pub was on roundabout - just continued until saw it. Mentions again how much it would have helped if had overall view map to look at.

Subject 9 - Route 1

Overall plan - didn't need large maps. looked at st map to find place and then looked for easily recognisable roads leading there. Therefore, was going to head along A52 until got into city centre and saw signs for A6 to Duffield. Would then turn off on Kedleston to destination. Spotted on map that had to go across at big roundabout continuing on A52. Was seeing signs for Matlock A6 - knew that Matlock was in the direction wanted to go. Was able to come off at the right point of A52 - saw sign in time to go to left.

Knew at this stage that quite close to where wanted to be - still following signs to stay on A6 - wanted to turn off onto Keddleston road at some stage and then off onto Elm. Because not safe to stop on 1-way wanted to get off and then find somewhere to stop. Could then find out where he was by looking at a street name. Actually continued on A6 and stopped past 1-way system - didn't see Keddleston as went past. Once stopped saw st name Highfield and realised where was - so turned up that turning to head towards Keddleston.

Once got to Keddleston thought that could go across any of the streets and would get to Parker st - tried a number of them - all dead ends "bad move that" - couldn't see that they were dead ends from road - would go around bends and then reach end of road - "bit frustrating". Went past Elm st and saw it was dead end - decided to go up it to find pub - then realised that couldn't leave car so felt should get to it the right way. Then took advice from passer by who said that had to drive around 1-way system. Felt advice wasn't that clear - just go around 1-way. Decide to take West ave - had been past before so knew where it was. Saw st name to confirm. Went to end of road and into Parker and then continued to pub.

Subject 10 - Route 1
Overall plan - looked on larger map to see generally where - was going to keep on A52 (didn't gauge how long it would be). Felt he would recognise when he was close to city centre (by traffic, buildings, road layout etc.). Also noted that A52 went right into the centre and merged with ring road. Would then look to get onto A6 (didn't have a place name in mind). Failing that he felt he would take the next big road A52 Ashbourne - recognises it is easy to miss these roads in inner cities. Also thought of looking for signs to Little Chester (suburb of Derby close to area) - but didn't see any as driving along.

Approaching Pentagon - thought he would be going over top - so a little surprised when he was taken down to it - but was sure of location. Looking for signs saying inner ring road and A52 at this stage. As came off Pentagon moved over ok - looking for signs for ring road and city centre. However, as continued he feels it was difficult to consult maps (traffic building up) - also, feels signs wee confusing at this stage - conflict as signs were pointing to city centre off to the left - didn't want the centre - so took inner ring rd signs. don't remember seeing signs for A6 - felt best to continue. Didn't realise had made mistake until saw signs for Ashbourne and no more signs with towns associated with A6. So went for A52. Took right along A52 Ashbourne onto Mercant st - knew that it went across to Kedleston which was main road near to destination. As travelled along A52 looking for side sts to help locate himself. Saw a side turn which he thought might be it - but edged towards filter - "keeping options open" until saw st name then moved over.

Was going to end of road (a main road) and then turning right. Not paying attention to its name. Stopped along the main rd and decided to turn into Quarn (thought would be able to get through to Parker) - could see from stopped position that Elm was a dead end (sign) (had also suspected this when planning at beginning. Drove out and formed final stage of plan before got onto 1-way system - could see road system in front of him. Went across 1-way system and back up until got to West ave - had planned this beforehand. Saw st name as turned into - then stopped and planned last bit - right at end and follow. Notices Rycote centre on map now - saw signs as turned into West Ave.

Subject 10 - Route 2
Overall plan - first trying to see how the different areas (pages) were in relation to each other. Wasn't sure whether to go on ring road or more direct route - decided to go on ring rd - traffic didn't seem too bad and felt that would be able to just keep on it bearing in mind A6 and A514 signs. Was aiming to go past A514 and turn onto Nomanton rd soon after (Normanton seemed a good direct line rd to destination). Felt at that time that he would be confident following map.

Retraced steps at start to get onto 1-way system. But after that "the signs get a little confusing" - saw signs saying that straight on was inner ring road and city centre - had in mind that wanted to go on ring rd - also saw signs for A6 Loughborough off to the left. Felt that didn't want to go "back where I came from". So continued onwards and got fed around onto ring road going the other way. Realised mistake "very quickly" - as soon as turned away from direction felt wanted to be heading. New plan - felt it would be too much hassle to turn around and go through all the side streets already been through - so went to originally considered plan - ie head through centre to Normanton rd. At this stage wasn't considering Abbey rd as a way across. Following signs for city centre to start with was going to cut into centre and weave through to Normanton on side rds (had in mind a number of different turnings to make. However, as stopped at traffic lights noticed that Abbey rd seemed a good through road to A5250 which them lead easily to Normanton (ie simpler route with less turnings - also avoided the city centre driving).

Stopped along it and decided to head along Spa lane - slightly shorter route through to A5250 - noticed that other drivers seemed to be going up it, so must be good idea - well used route - saw st name as approached. Original intention was to then to turn off A5250 (saw it as main rd - hadn't noticed rd number) onto Mount lane and through to Normanton. However, no entry so continued and turned right away from signs saying city centre and parking etc. - knew had to be going other way. Saw sign for Normanton later along road - wasn't sure up to that point. Final stage of plan was to follow this road all way - thought would stop at some stage and check final part - couldn't tell from map that road would be so busy. Trying to see how far had travelled down road by street names passing. Didn't pay attention to churches etc along route. Got to junction (mini-roundabout) where needed a decision quickly (50:50 decision) - had forgotten direction that needed to go and inconvenient to consult map so turned off and stopped shortly after. After stopped realised wrong via looking at st names. Turned round - and turned into Pear Tree (saw sign so was sure of turning). Then just continued to roundabout where saw pub on corner.

Subject 11 - Route 1
Overall plan - along A52 looking for signs to A6 North (had Duffield in mind but points out that wasn't signposted for that). But knew Matlock was "towards the North". Noted the "spagetti junction bit" and the roundabout. Junction after pentagon was the one slightly worried about - how to handle it. Looking at it seemed that would have to come down to a roundabout type junction - knows now that was underpass. Guessed that Garden st would be one-way - split of a main road. And would just have to take Keddleston or West ave once on 1-way (noted before set off).

Didn't notice signs for A6 at Pentagon - at this stage knew had to continue following signs for A52. Cut across afterwards - quite clearly signposted A52, A6 Matlock. Also clearly signposted to turn off A52 for A6 Matlock. Notes that both these junctions seemed to come up very quickly - not quite ready for them. Wasn't looking for anything else. Notes that his plan was very general beforehand - became more specific as matched road to map approaching turns (I think based on behaviour). Choose Keddleston ave to take because thought that West Ave might be a 1-way feeding in (since slightly larger) - knew as got onto 1-way that Keddleston would be 2nd on left (looking at map to check). Didn't see st name until turning into rd. Parker st was first on right.

Subject 11 - Route 2
Overall plan - Looked at overall view on AZ to see where he was in relation to that and how pages fitted together - thought that quickest way there would be onto ring road (back way came) and round clockwise and round to A514 - then turn off to Douglas and follow to destination.

Backtracked to start with working from memory to get onto 1-way. Followed around aiming to get back towards ring road - looking for signposts for A52 and A514 (thinks it was signposted from that point - but not sure). Also looking for signs saying ring road - feels that the turning came on him a bit quick - thought he would have to go on a bit more - Didn't see little slip road on map and thought he would continue and then go over some flyover arrangement. It was A52 ring road that made him turn. Was definitely signposted A514 all the way from here - "quite straight forward really". Mentions that purposely didn't choose other way round because there wasn't anything really that connected main roads and would have to make more turns. Knew that had to go over big roundabout (didn't know its name) and then turn left at second smallish roundabout afterwards onto A514.

Knew was going to go over A6 too. Once on A514 and in immediate area starting matching st names (didn't notice others apart from Douglas before set off). Was looking for Reginald - saw it as stopped at traffic lights. Then knew it was the 2nd turning on the right afterwards. Knew Grange st was one before too. Mentions that unless he feels a turn is going to be completely obvious he will take note of one or two st names before so know getting near to it (when there are lots of side turnings). If few side turnings he will count right from the start and might not notice other st names (just the one going into to be sure). Turned into Douglas - saw st name as turned into st. Was just going to keep going at this point. Saw that Princes st was on roundabout, but still got a bit confused when saw different pub earlier and thought it was it the one (was expecting turning to come up a bit quicker this time). Didn't notice st name changing - knew Vulcan arms was on this road.

Subject 12 - Route 1
Overall plan - Wanted to follow A52 as much as possible. Looked to see where destination was in relation to A52. Didn't have a plan for coming off A52. Was going to wait until got into centre and then start planning (stop if could) what to do "time to start thinking now". Was going to reference something off map to see how far along A52 had travelled.

Followed A52 and referenced Pentagon when got to it ("saw signs for A61 and didn't want to go up that"). Coming off pentagon looked at map and realised where was and that needed to keep to the right as much as possible. "you'll see some appalling driving on video" - turned lane very late. Without planning - following flow of traffic - ended up on A6. Realised afterwards that needed to get onto A6 (near to destination), but didn't see signs for it until actually on it (just before got on 1-way) - feels that tuned off mainly because "stuck in that lane". Mentions that when normally drives to a strange place will get so far and then think "its time to stop now", and he will reference a map.

Once knew on A6 knew that didn't want to stay on it, so turned off - knew that taking a left would get him closer and in the right general direction. Didn't know that it was Keddleston that turned into. Stopped further up road opposite side turning and spotted st name - enabling him to locate himself along road - had also remembered some other st names that had passed. Turned around and headed for Elm - saw as turning into that was dead end- thought that still might be able to get to it, but couldn't. Then had little panic attack that had gone to wrong Elm st - so checked that did intersect with Parker (hadn't checked this before). Then turned around again and headed for next st - this wasn't signposted as dead end - but still was when got there. so thought "sod it! I'll have to go through 1-way system". Spotted little cut through on 1-way and went onto Keddleston and then Parker and onto Pub.

Subject 12 - Route 2
Overall plan - took some time to see where destination was - found out where it was. Looked at the main roads in the area and tried to reference where they were on map(used main map, since found it difficult from A-Z - "had to keep changing pages"). Felt had choice - knew from little bit of knowledge that if found A6 "would never go wrong". Wanted to head round ring road and look for signs for A6. Realises now that should have aimed for A514. Thought that A6 was the important one - could then go across (had Litchurch lane in mind) to A514 and down to A5111, along and then up to destination.,

To start with went back the way that he came ("had already done a bit of driving in this area - knew the people personally!"). Then looking for signs A6 (and towns in South direction - thinks they said Loughborough). Saw them and it lead him onto ring road clockwise. Feel that had to nip across not to continue on the A52 (the video tells otherwise - he actually went onto the A52 heading back to motorway). Is very adamant that he was on A6 (or at least heading for signs for A6 (which he probably was). Talking about coming off the A6 into an industrial estate - "honestly doesn't know where it was". Turned onto industrial because saw signs ahead saying to turn off for A6. Slip road was coming up and so he went up it (actual turning A5111 heading for A6 was further up the road - probably didn't see or take in distance) - remembers seeing Sainsburies and feeling by types of roads that gone wrong way - so turned round at mini-roundabout. Thinks that they've just built the road off to the industrial park, but kept the original signs close to it.

Didn't stop and reference any maps - just got back onto main road (what he thought was A6 or heading for A6 around ring road, but was actually A52 heading for A6 the long way round). When got back took turning off signposted A6 Loughborough and thought he was definitely on it then. Couldn't see Litchurch ("missed it") so continued to roundabout at end. Knew had to find the A5111. Got to bottom and turned right at roundabout (probably thought that would take him towards A5111 based on him thinking he was on A6 heading south). Now seems very unsure as to where he is on map - long pauses while tries to work it out. "trying to remember which way I came". Now feels that may have possibly gone round the A52 way. Definitely remembers seeing signs for A6 all the time - so assumes going way that considered at beginning. Fact that can remember vividly turning right at roundabout and then stopping just after at Litchfield dr has made him reconsider.

At Litchfield relocated himself (knew had gone wrong at previous roundabout because as turned saw sign saying A6 Matlock and city centre). Probably didn't realise the extent of his errors at that stage because only had certain pages of A-Z in front of him and only looking to get onto A5111. Along A5111 referenced at side st (stanley road) so knew going the right way. At A514 saw lots of signs heading back to city centre - didn't take much notice of fact that A514, just knew had to continue past main road. Aiming to continue to roundabout "island" - saw it as good place to turn - road would lead to destination. Lots was new to the map (building showcase cinema and MacDonalds) - slightly concerned that roundabout wouldn't be there, so noted that mainish road going off to the other direction and that road was Stenson. Found it ok.

Then stopped just as went into Stenson - could see a complicated road layout ahead ("islands and lots of turns") - thought that if turned off could be in trouble - so stopped and located himself with St Vicent st. Could see that needed to go almost straight - saw Walbrook as got there. Then continued to destination. Hadn't realised that on roundabout. Knew on junction with Princes st so looking for that (never saw it though - saw pub though). Notes that doesn't look for landmarks from maps - his usual strategy which occurred here is to "plough into an area" and then look for some reference point - does like landmarks in directions given by others though.

Subject 13 - Route 1
Overall plan - Estimated that 8 miles to city centre along A52, then aiming to track ring road (could see that would be ring road) - intended to turn off following signs for A6 Matlock onto King st and then off further on onto side sts where would work out last bit to Parker.

Along A52 - could see that for 1st 6 miles knew that would be out of city - using distance clocker on car. Had noted big roundabout beforehand and that had to go over - also following signs for A6. Got confused as came off roundabout. Had view that had to keep quite straight. - felt that moving into right hand lane was taking her too far over to right, so stayed in left lane and then got veered off to the left (towards cockpit). Did see signs for A6 the way that went (not sure if said Loughborough though). Realised mistake as went over river ("oh no-shouldn't have done that"). Passed the river and thought "that's a landmark - where am I" - so checked on map - Knew than that shouldn't pass the river until a bit further at least (near the A6 turning). So decided to follow roundabout around and back onto A52.

Once back onto ring road saw signs for A6 and turned off - could see how road would look - was checking with map as went along. Could see that fork in road further along at Garden st. Didn't see it as 1-way system beforehand. Stopped once got there (junction of Lodge lane and Bridge st) and checked map to be sure exactly where was. Realised that in right area. Could see that needed Keddleston and not to continue on A6. Turned around and back onto 1-way system. Looking for fork in road (didn't count side sts) - was going off on one before A6 at fork - didn't see it as Keddleston. Saw Garden st as short st and fork at end. Once on Keddleston turned first left into Elm st (saw as went in that dead end). Thought about stopping and walking down to pub, but couldn't leave car so replanned. Thought that could get to it via the next st (do "three sides of a square") - didn't work either.

So in end went all way round. Mackworth was very clear. Other sts unsure as to how they all linked from map. seemed better to go around a bit - "a little effort for potentially better results". Working off st names to get around - stopping quite frequently to check. Never counted sts or looked for landmarks in this area. Didn't even notice recreation park as went past.

Subject 13 - Route 2
Overall plan - didn't want to go through the city centre. looking at map - didn't feel that there would be much it in terms of distance. Seemed relatively straightforward. Because had spent so long looking at the map was aware of where the Ashbourne A52 was and from the front of the AZ could see where all the main roads around Derby were. Was going to turn right onto A52, then onto A38, A5111 and up to destination (turning left at roundabout where Normanton park was) along Stenson and straight onto pub. Didn't want to go on inner ring road based on problems had before on that road.

Reversed journey to get to A52. Saw sign saying no right turn. So went left and turned into first side turn and turned around so could get back onto A52 the right way. Along A52 was looking for signs for A38 - knew had to go left at first major roundabout. Didn't have a place name in mind. At next major roundabout was looking for A511 off to the left. Feels that this was easy to find. No place name in mind or road names along here. Notes superstores now- hadn't noted them on the map during the journey through. Knew would be going past 2 big junctions (didn't know the road numbers). Knew it wasn't a long distance between junctions. Primarily looking for Normanton park and roundabout at this stage. Didn't see sign for Normanton park - but saw green area, trees etc. whilst approaching roundabout - up to then it had been houses - surbubia etc. so decided to turn off to left. Knew wanted to go onto Stenson and saw sign at roundabout pointing to Stenson in other direction - momentarily confused - didn't think it was off to the other side too (way shown on map as extended letters - she hadn't noted). But was quite sure in head that was going left at roundabout so took it.

Knew had to get onto Walbrook rd. Junction with Upperdale rd a bit confusing too - relatively easy to go off to the left - bigger domineering road - but looked at map and realised need to go dead straight on. Then just looking for pub. However, hadn't realised that on Walbrook and hadn't realised that pub was on roundabout so went straight past it - notes that Walbrook road seemed quite long. Trying to find a street name to locate herself - remembers seeing Joseph but no others. Was unsure of distance that had travelled - thought it would be further up road. Saw st sign for Dairy House and realised that must have gone too far (was aware that this was past pub) -so turned around and came back. Didn't note any landmarks in this area.

Subject 14 - Route 1
Overall plan - looked at map - from roundabout where A52 "essentially ends" looking for main roads to get close to general area. wanted to get onto ring road and then A6 to Duffield - once on A6 looking for island (five lanes - although didn't note name) which saw as focal point where could turn left onto West Ave - felt that with this side st being on island it would be a readily identifiable turn. Was going to a point, which he felt would be better than just heading for a road, where he would have to constantly reference where he was on the road. Wasn't sure how the Garden road stretch would look beforehand - "didn't say that was 1-way" - but notes that on colour map shown as part of A6 so knew that would still be main, but wasn't sure exactly what he would hit. Knew that whichever way he went he would still get to island at top. Felt that would be able to stop once off main road and check final part of journey.

Along A52 - "book in hand" - following signs for A52 - went over big roundabout - could see this on map - intention then was to go under underpass and around to A6 junction, but actually went off to the left toward the cockpit - "just a lane error". Was in the inside lane off the Pentagon and next junction came up on him "very quickly". Problem was that book was folded over (between the two junctions) and he did not have a "sensible idea of the distance he needed to travel". So hit next junction while still on inside lane coming off on fast road and couldn't get across to where he wanted to be (ie because of fold wasn't prepared for next turning). Saw signs for knew had made mistake - referenced map as slow moving to go back around roundabout and onto ring road.

Then looking for signs for A6. Nearly made mistake.as came off cockpit - from map inclination is to be on inside lane (so could turn off on A6). However, this was leading him off ring road again back towards A52 to motorway - "so had to do a bit of a dodge there too' to get across lanes. Was signposted though which allows him to cross over. Then saw signs for A6 Matlock and took the correct turning off ring road. Had also noted from map that needed to go over the river before turning off for A6. Stopped shortly after getting onto A6 - near a mountaineering shop - to check exactly where was and what the last part of journey was. Sticking to original plan. Wasn't counting side sts - just drove to last turning on the left at the top of the road where layout was as saw on map and turned left. Didn't see the island. Checked it was West once on it. Then drove to end went right and continued to pub.

Subject 14 - Route 2
Overall plan - first thing did was to check where was according to page references. Looked at overall map to link them. Was looking for A514 from ring road (had been to cockpit so no problem) and then A5111 (a main reference road that was just below destination). Was going to count roundabouts along ring road after the cockpit to establish the A514.

First part of the route was back in reverse to get to 1-way system. Then "clearly signposted" to get onto ring road - kept in left lane to get onto ring road. Then following ring road around past cockpit. Notes that A514 was quite well signposted anyway. Hadn't noted that passing A6 turning - just left at 2nd biggish roundabout after cockpit (where had just come from). Not noted that Omaston or that would pass Hospital ("obvious when you get there though"). Found it no problem - when on A514 problem with map orientation - was holding it North up, but was actually heading South - so thought he was at the bottom of the page and was looking to turn left, when actually he was at the top of the page and should be turning right. So actually went the wrong way up the A5111. Feels that this would have not happened if he had planned better before set off so that he was looking for a side st off the A514 (eg Douglas). As it was, he was going to A5111, and he seeing signs for that, so he thought he was still doing the right thing. Also, when actually driving because thought was heading up page, thought that would hit main road before any of the residential streets off to the side, so didn't think to reference side streets or anything else as driving along. "just going for the A5111".

Realised mistake quite quickly after turning wrong way up A5111. Had started to look for st names, so could locate roundabout further along. Was mainly looking for Nightingale road (first main road should pass) - But soon became apparent wasn't coming up - also, was passing roads not where he was looking on map - then saw them on other side of A514 - "clicked". Turned around. Now heading for island - first roundabout would come across - spotted Nightingale and was then sure that heading in right direction. Also looked for Elton - main x-roads that would pass. was fairly obvious. Notes that road layout has been changed a bit here - some small roundabouts with roads off to residential areas - but obvious that new and he was looking for junction with Stenson rd. Was referencing st names to reference distances. Didn't note that passed station. Saw stenson off to the right and took it. Stopped shortly after taking turning - saw that was just straight ahead on to pub. Saw Walbrook st to confirm on the right road. Was looking for nursery school to check how far had travelled along Walbrook , but never saw it. Also looking for traffic island - "was obvious point of reference". Saw roundabout and then saw pub.

Subject 15 - Route 1
Overall plan - locate A52 - felt that it was a good road to stay on - went close to destination. Was looking for the first big turning off A52 once gone over river - would turn left - swing off to the right after - saw it as slip road - would then work it out once there. Hadn't spotted that road would be A6. Was going to take the 3rd turning off once onto A6.

Along A52 - didn't have any real concept of distance to travel. Hanging on passing river. Looking to stay on A52 at all costs. As got off Pentagon got swerved off to the left - didn't realise mistake until got to the cockpit - also hadn't passed a river (didn't see river as passed it on ring road - "hadn't noticed it at all"). Doesn't remember seeing signs for A52 off to the right. Was actually using red book which doesn't show road numbers as clearly as A-Z. Mentions that his map (using city centre plan) - didn't join outer roads and inner roads clearly so wasn't sure at what point he had entered inner map. ie didn't have the overall view. So thought he might have come in at the cockpit and not higher up at Darwin place. Then saw from his map that A52 actually swerved up and so turned round at the cockpit.

Then back onto ring road in right direction and looking for river - mentions that also looking for St Martins church on his right (on his map). Wasn't sure about river - saw parapet and suspected that there might be a river there - also saw a main filter road - but didn't actually make the turning - wasn't confident at all so continued. Saw Agard st off to the right and located it on map - then knew exactly where he was and that he had missed turning. Saw in front of him main road - didn't see Friargate - just knew that it was next road and was main so decided that would take it and then the next on the right. Did that and saw Bridge st before turned into it - so was positive that had done that right. Plan from there (was stopped at some traffic lights and so had some "thinking time") was next left and next right into Keddleston gdns - however, keddleston was a) deadend, and b) had no sign. So replanned again - and decided to go out towards main road. On his map ought to of been possible but wasn't - on AZ less clear. Went to end of Bridge, then first left onto Garden (main road) and then 2nd left onto Keddleston - "from which point I was fairly safe". On his city centre blow up map it didn't go as far as Mundy st so didn't consider going off to the left as option (feels that might have if his city centre map went over to different page). Wasn't sure that he had turned onto Garden - had no choice as 1-way - was positive when 2nd left was Keddleston.

Subject 15 - Route 2
Overall plan - thought it would be a problem to go straight through the city centre - too many 1-way streets and traffic etc. So decided to go around the outer ring road. Joined different pages together in his head - originally was going to go up Uttoxeter new road and then along Abbey st - decided against this later (on basis that would have to weave through streets at end of Abbey, looked messy at junction with Uttoxmeter new and turn off A5111 looked "quite clean' from map).

Came out way came and then got onto Keddleston road - saw sign so knew exactly where he was - as travelling along this road looking for ring road signs (not really thinking of it as outer) and A38 - also knew it would be off to the left. After this still looking for signs for ring road - didn't see it as 2nd roundabout - also looking for signs for A5111 - took this no problem - then turned into Uttoxmeter new road (wasn't sure so stopped and saw Albany road on left to locate himself) - then looked at map in more detail and realised "that I was heading for trouble" and saw better route. Turned around and went back onto A5111. Along the A5111 looking for first roundabout. Made some checks as going along road - passed Burton road (didn't see it as A5250). Also made sure that passed Carlton road and the park (kiddies play equipment, opens space, bit of grass) before roundabout. Turned left at roundabout onto Stenson - saw st name - feeling very confident at this point. From here had it in mind to just continue straight onto Walbrook and then onto destination. did check for Walbrook (saw it) - on his map Walbrook doesn't intersect with Princes - didn't worry - just stayed going straight ahead - didn't notice that pub was on roundabout (not on his map anyway) - didn't see Princes but saw pub no problem.

Subject 16 - Route 1
Overall plan - stopped once on A52 and did planning there - knew how to get to this point, and had been told to come off at A52. Planning to stay on main roads until got near to area. Would then stop and work out final route to destination. Had in mind would be looking for A6 once on ring road - didn't have place name in mind.

Didn't note distance to travel along A52 - just looking to stay on A52 and see signs for A6. Went over first roundabout - had noted this beforehand. Feels that it (the A6) was signposted quite clearly, and had no problems. Remembers passing signs for West Meadow industrial estate and seeing it on map which confirmed that he was going in the right direction. Came off on A6 - got to 1-way system - then a little confused. Stopped as soon as could (along A6 after 1-way) to work out where he was. Notes that he was thrown a little by the 1-way system. Wasn't expecting the road to look like this. However, he says that he was aiming to just get to the general area anyway, so not too bad. Noticed st name Duffield road, so knew where was. Then decided to reverse and go back onto 1-way and turn up one of the side turnings - didn't have a particular street in mind ("just aiming to turn into the general area - then it just fell into place"). However, now not sure where he turned. After some thought feels that he turned up West ave, primarily because it turned out to be so easy. The turned right into Parker.

Subject 16 - Route 2
Overall plan - has noticed now that destination is close to Derby football ground - feels that if he had noticed this would have got there no problem - anyway, looked at city centre map in Atlas maps. Noticed the train station and hospital were in the right direction (roughly southerly), so wanted to head for them first - following signs. Hadn't thought about where exactly his destination was - "was going to do that later".

Had noted the A5111 beforehand on the A-Z (saw it as Omaston rd - didn't see the Park bit when quickly scanning), and that it was close to destination ("wanted to be there"), but doesn't feel that he knew where other main roads were. Looked at the city centre map on atlas and saw Omaston rd on that (actually A514) and assumed that it was the same road as where he wanted to be (ie the A5111). - this caused problems later (although he still thinks it worked out ok). Looking for Bateman road (off london rd) to get to Omaston (which he saw as road close to destination). Mentions he thought the hospital and train station were closer to destination than they actually were, and that it would have been a lot easier if he had the overall view.

Initial part of journey - went back way came onto 1-way - looking to go back towards the city looking mainly for signs for railway station which he felt would be clearly signposted. Went onto main ring road (saw signs for inner ring road) - hadn't actually seen signs for railway station or hospital at that stage, but could see from map of city on atlas that following ring road would take him in general direction. Once on ring road - mainly looking for signs for railway station - saw signs for railway station approaching cockpit, and turned left at roundabout - didn't really know which road he was taking at that stage, just aiming to get close to railway station. Went past station and continued up to junction with A6. Turned right heading for city centre and hospital - saw these as places to aim for. Stopped opposite hospital to work out exactly where he was. Looked at map and then knew than that he was probably on London road, but facing the wrong way (knew from where hospital was in relation to him)

Wasn't aware that on A6 - hadn't seen that on atlas map. Turned around and continued looking for Bateman st on right (very clear as cut through road on atlas city centre map (- NB none of others shown), but not viewable on A-Z (on fold)). Didn't see it. - just kept going. Only road looking for. Much further down the road "was getting a little desperate" - had passed a lot of turnings. So decided to stop and ask someone. Asked elderly couple where Bateman st was ("never heard of it"). Then asked where Omaston rd was ("do you mean Omaston rd or Omaston Park rd?" - he said "Omaston rd", and they then gave directions to get to A514. Turn right at first roundabout, right at next. Under a spider bridge and the Omaston rd would be apparent (he's not sure whether they told him to turn right after bridge or not).

Did first part ok - once on A5111 saw signs A5111 Omaston and just continued - knew that on right road then (had noted A5111 before as road close to destination). Stopped some way along A5111 to look at A-Z - saw that once Omaston changed into Kenilworth he was in the right area and he needed to turn off to the right (had noted that side turnings along Kenilworth lead to Walbrook which he knew lead to destination). Retrospectively, he can see that he should have continued to roundabout and turned right and followed road, but didn't see that at time. By the time he had seen a sign for Kenilworth ave he was past the turnings he wanted. Had seen Derby lane as passed - so turned in and went back to Derby lane - video suggests he went back and forth a bit here (probably unsure as to where exactly he was). Went up Derby lane - stopped along here and saw a st name (Randolph). Then knew that had to continue until got to Walbrook - didn't count streets - just driving until got there. Saw Walbrook no problem . Stopped there to locate final destination. Noticed that had to pass Portand st (on both sides) and Princes st would be after that. Hadn't noticed the roundabout. Continued, saw Portland and then the pub shortly afterwards.

Subject 17 - Route 1
Overall plan - carry on A52 past roundabout - felt that road pattern looked as if it could be confusing (notes that unsure whether would be going over flyover at roundabout- but was confident would know when got there - "major junction with A61") - Had noted that would be on dual c/way until first roundabout. Also noted that approx. 8 minutes driving, 8 miles or so.

Decided to follow road signs for A6 after roundabout (knows that Matlock is in that direction - hadn't thought of this beforehand, just wanted to be going North on A6). After this he felt that the five lanes junction would be fairly obvious, "because of its complicated nature". Intention was to turn onto Keddleston st or towards place Keddleston - once had done that would pick up Elm st straight after. Felt from looking at the map that he would have to stop and reappraise once he got to the general area ("looked very complicated around destination")- was aware that no direct link between Elm and Parker. Traffic stopped approaching roundabout so had plenty of time to check that was on target. Saw signs for A61 and signs for A6 Matlock on 2nd exit (notes that on ground it seemed left, but on map is straight on). Didn't have any problems with signs - clearly signposted on side and on ground. Stopped looking for A52 now. As came off roundabout moved over 1 lane to keep following signs for A6 Matlock - knew that junction with A6 was "potentially tricky" - felt that it would do "a sweep and turn sort of thing, but can never be absolutely certain" - so locking onto A6 Matlock signs still - very clear - "no doubt in my mind that everything was ok" - made turning onto A6. Hadn't noted the river - doesn't tend to use these in urban areas "pretty useless - so obscured"- does, though in open areas.

Wasn't sure what he was going to do from here - got forced around by 1-way system and so wasn't sure where he was. Was confident that hadn't reached Keddleston (at fork), but didn't know how far to go. Stopped just after he had seen st name with Garden to confirm where he was on map (saw Kings close). Could actually see to the end of the road. However, it was still not clear how exactly the road would go - so he aimed for the top of the road and was looking for Keddleston. Felt that the area before Keddleston was a bit messy so didn't turn earlier (getting to Elm seemed easy to do - into Keddleston and first left into Elm) - realises now that this was not the best decision. Saw Keddleston once got there. Didn't count streets to get to Keddleston - notes that on ground junction looked "more twisted than on map". Had suspicion which one it would be - looking not for a hard left - "a straight on with a bit of left in it".

Got to Elm - saw it was dead end as turned in - knew that there would be a bit of a complication here - explains that part of rationale was that if he had time pressure would have "been a doddle to leave the car and walk through to pub". Reappraised - "got interesting then" - because map was such a mess felt that could go up next road through to Parker, but couldn't (turned in and had to reverse)- then decided to turn into Cowley - could see that this would get him into area - obvious that cut through from amount of traffic going into it and waiting to come out. Also, obvious that this road was going somewhere since it was at end of residential roads (70s flats redevelopment) and would be able to go around - didn't notice that it was Cowley until later. Once into Cowley turned into Watson thinking that he could get through, but "still a mess" a dead end - turned around, and saw Cowley so knew exactly where he was. Saw that if turned left would go past some green area - beyond that next left into Markeaton and left on St Nuns - after this wasn't sure how he would be able to get there. Fact that words Kingsmead centre is printed over Keddleston gdns road meant that he wasn't sure whether he would be able to go up that road. Saw the Green - turned into Markeatan (saw st) and then at end into St Nuns - had noted that was slight dog leg with Mill (saw that st no problem). Decided to follow Mundy (could see street) - Also, could now see from the ground that Keddleston gdns was a dead end. Knew would have to follow round. Saw Leaper as went past and continued to end and then onto Parker and to pub.

Subject 17 - Route 2
Overall plan - used AZ to locate destination - thought that area around destination looked a real mess - but then thought that Walbrook might be a more significant road, because followed on from roundabout off outer ring road. So got out OS map - which shows the road "very clearly". Yellow rd. Could also see roundabout at destination on OS map. So thought that could use main rd route to get there. Was looking to go back way came and looking for signs to get south of Derby to get across to A514. Had also noted (clearer from OS) that roads to east of city centre were best ones to get to the south. Felt that those to West were not as clear and were less likely to be clearly signed. Noted that would have to go past A6 to get to A514. This threw him when on route.

Took first left and then onto 1-way to get out (knew the roads from here). From there looking for signs to get South. Had in mind inner ring road, A514 and A6 Loughborough. Knew that would have to turn to the left and did (saw signs for inner ring road, city centre south, Melbourne A514, loughborough A6). However, hadn't associated the destination of Melbourne with A514 beforehand. Therefore, as came off slip road followed sign that said A6 Loughborough (took this as overriding information because didn't know about Melbourne). Realised too late that should be following signs for A514 Melbourne - was in wrong lane - heading for A52. Knew almost immediately that had made mistake (sweeping off away from ring road). Decided that would turn around at next roundabout - knew it was there and so could do it - had to go down slip road - stopped briefly and did quick check on map just to reconfirm A514 turning (there was also A516 nearby and he was concerned that might head down wrong one - "as numbering sequence a little bit dodgy"). Felt that once he got back on route feels that it all became very easy. All clearly signposted (ring road, A514). Had to stop at traffic lights - gave him thinking time - check map as to where exactly he was. Chose to ignore signs for A6

Loughborough now (realises now that the previous signs were trying to get people lower down on the A6 to avoid the city centre).

Turned onto A514 - wasn't interested in the st name. Next reference point was the hospital (noted it on the OS map) - needed to pass it along the A514. Then looking for Douglas st - also noted that if went anywhere near a railway feature (probably a bridge) then had gone too far. From OS map because Douglas seemed such a significant road was going to look for signs for Normanton too. Not looking for other sts - however, as came past hospital saw a main road off to the right and thought that this was his, so moved over- however, as got nearer saw that it was actually reginald and "safely aborted". "looked reasonably significant road". As continued saw signs for mini-roundabout (what he considered to be a reasonable junction) and although didn't see signs for Normanton or Douglas committed himself to making turning by moving into right hand lane. Confirmed as made turning that on Douglas - didn't see signs for Normanton. Then knew that if continued down road to roundabout would reach destination. Wasn't interested in any of the other side turnings. Knew that next roundabout would be on ring road and he knew that if he saw that had gone too far.

Subject 18 - Route 1
Overall plan - A52 follow - knew where Meadow st was (been there) - first of all, he located destination in relation to this. Was going to stop there and get his bearings - when he got there he got rough idea of scale from maps - so that junctions didn't come up on him too quickly.

First part of journey just following signs for ring road A52 - knew this part - went over at roundabout. Feels that subconsciously he was keeping the sun on his right to be sure that he was still going in the right direction. Turned off onto Meadow rd - feels that map is wrong (don't go under the bridge) - could see that would be able to get back on easily - knew that would be able to stop no problem. From there planning to destination. Main information looking for was signs for childrens hospital (decided to use it as close to destination - and remembers seeing signs for it as came off dual) - thinks that it was signposted later but still missed turning off dual c/way.

Didn't see it as A6 - just main arterial road - was hoping it would be a straight on (ie keep on road), but it did swerve off to the left. Feels that because of road works got sent off in wrong direction and missed the turning off ring road. Also, mentions that nearly turned right onto Mansfield rd - was signposted to childrens hospital - decided against this because didn't want to got to Mansfield, so changed lane. Mentions how he was being forced different ways by the 1-way streets and lanes. He seems very unsure as to where he actually went - he is contradicting himself a lot - Mansfield was a hard left and then he feels that the sign was actually meaning that he should stay in the straight on lane. Feels that he did come off on A6 (two contradictions beforehand! - probably accident more than judgement - might have been because of traffic/ roadworks) - I think what he was meaning about the hospital now become clear - saw signs for hospital possibly right (or straight on) but was taken by flow of traffic and went left into St Helens - notes that deceiving from map - King st and Helen same width. Was not sure where he was after this - sent in number of different directions - thought the road he took would head in right direction, but seemed to be going away. So stopped and checked location - saw that on Ford and immediate thoughts were to get back to where he had come from. However, was forced off to the left by 1-way system into city centre. Doesn't feel that would be able to go up Friargate from that direction anyway (I think you can).

Turned off Ford looking for somewhere to park - Used St Werburghs church (using super red book) to reference himself once stopped- saw pub "hoped it would be the one wanted" - so obviously quite lost at this stage. It all seems very hazy where he went after this. Got out to A52 Friargate - know this road "can get out to golf course I go to" - still having problems explaining "oh sod it -watch the video". Looking for names on side - traffic slow moving - using this to establish where he was as going along. Turned into st Nuns - couldn't turn into Bridge st - wanted to "oh **" - went to next one. Now thinks that he went up Keddleston - I point out that he couldn't do this - dead end and he changes his mind again. Confused by fact that Brook st (a minor road) was split by major road - usually they will be called different names on each - therefore, when got to end of road he actually thought he was further along road (back at Ford) and so needed to go round block - went left and then left again up small road to reverse - had realised that was not the same road as before (ie Ford) quite quickly. Then realised that Brook st split so went along Bridge - saw st name Garden and knew exactly where he was. Didn't count streets to find turnings - knew that had to go up one of roads on left to get to Parker - turned up West ave (saw sign as turned in).

Subject 18 - Route 2
Overall plan - saw hospital on overall view - wanted to get to A514 which was near hospital. Once on A514 was looking to turn off on Shaftsbury - on his map doesn't show it as dead end, but was when got there. Wanted to avoid city centre, "but got sucked in" Also looking for signs for A6 Loughborough.

At beginning went back way came - Saw sign just after 1-way saying A52 Nottingham (off to the left), inner ring road (straight on) - felt that didn't want to go towards Nottingham so continued. After this decided to cut across city centre towards cockpit (has been near there before). "can't honestly remember where I went after that" - had decided not to go on inner ring road (felt that it was going to take him out of the way) - plus traffic looked appalling (lots of roadworks). Mentions that although he was transversing roads he had been on before, he didn't recognise them, since going in opposite direction. Once got into centre signs for main roads "dried up". Passed Assembly Halls - Been there 10 years ago. So knew heading in roughly the right direction. Was turning into roads aiming to head in generally the right direction, but some of them turned out to be cul-de-sacs (one of them took a long time before told you that dead end)

At some stage saw sign for A514 and kept followed that - didn't come out at A514 - actually came out west of it. Hadn't realised beforehand that Derby football ground was so close to destination - otherwise would have got there dead easy. Points out that all this didn't take very long - this is the way he does things (cavalier general heading in right direction) - the route he describes generally for getting out to A514 is not the one on the video. Once out at A514 recognised where he was. Did see some st signs as he was driving along - helped to locate himself a bit. Saw the hospital as he went past. Was looking at some of st names as went past to help locate himself. Plan was to turn into Shaftsbury - realised that it was turn before bridge - saw it coming up and also knew had to turn - wouldn't be able to get across once past railway line. Shaftsbury was cul-de-sac so pulled out - re-planned and worked out that could go back and take next left (Douglas) - then counted that it would be 6th on the left to get to Princes. Also counted off the st names. Had seen Douglas before so knew where to turn. On his map doesn't show it as roundabout, so counted 6 - ignored first one as tiny road- also looking to check st names all way along so be could sure was getting there and there were no new ones. Because on his map Walbrook didn't intersect with Princes - this was just to get him close - but he saw roundabout and then saw pub.

Subject 19 - Route 1
Overall plan - to go up to A52 until reached first big roundabout - has been to it before when cutting through to Ashbourne. Took note from A-Z that roundabout was junction with A61, so could be sure when got there that right one. Using main A-Z. Didn't like red A-Z, since didn't have streets marked clearly. Looked at street map of Derby in Atlas to check. Knew had to follow A52 past roundabout. Would then look for signs for A6 Matlock or Belper (two large towns outside Derby on A6 saw on Atlas). Had feeling that road would go off to the left as slip road and then swerve to right. Then thought that would split into 1-way system (could see from map that dual c/way stopped and then became single just before road spilt, so was pretty sure). No note of distance to travel along A52.

Just looking for following A52 to start - doesn't think there were any road signs for A6 until after Pentagon. Waiting for big roundabout. Wasn't looking for signs for ring road - saw that as further out (actually outer ring). Picked up signs for A6 Matlock as came off Pentagon. Few problems getting across lanes to make turning. No note of river. Thought that road would go into Garden st - was then aiming to make turning into West av just before road started to come back on itself. Could see that road would fork (with 2nd part of fork being A6) - wanted to turn just before this. Didn't count streets along here or note other streets passing nearby - didn't see st names for Garden st but had strong feeling by layout of road where she was. Didn't see West Av as she made the turning - just went for it. Then carried on to end of road and then into Parker - didn't see st name - wasn't really looking - but sure that on right road. Mentions that marked the map (in pen) around the last bit of journey - helped her to pick out the roads when looking whilst moving

Subject 19 - Route 2
Overall plan - looked it up on AZ - saw that was close to A5111 - looked this road up on big map (Atlas), but it wasn't there - so looked at front map of A-Z to see how could get to it. In terms of getting from A5111 to destination, contemplated making turning off before Peartree station - but then looked again and saw that would be best to turn off at roundabout - would be clear (type of junction and fact that came at end of a dual c/way stretch of road) and lead straight to destination. Used 1:50.000 map to determine the main roads to take to get to A5111 (Firstly, Keddleston - had seen when turning down West so knew where it was, secondly, A38 heading South towards Burton)

First part of journey was way came - wasn't looking for st name for Keddleston - first left out of West ave. Then continued looking for A38 Burton - doesn't think saw Burton on sign, but saw A38 and knew which direction to head. Then just looking for A5111 (didn't have a place name in mind) - retrospectively feels that would have been better to have counted the roundabouts (ie 2nd). Never saw signs for A5111 in that direction ("couldn't believe before that it wouldn't be signed"). Thought the signs might pick up internal place names like Pear Tree and Normanton (had noted these beforehand), but they didn't. So continued past turning - wondered if had gone wrong at next junction (slip road for A516) - thought might have got numbers wrong - hadn't noted which A roads would pass en-route. Beginning to think at this stage that had gone too far - but not sure. Was sure that had gone wrong further down A38 when saw place names which when checked with the map were further South than she wanted to be. So turned around and headed back way came. Noted this time that it would be the first roundabout - saw signs this time - "signposted this time" - wasn't sure if it was the one that passed before.

Along A5111 knew it would start as single c/way and then would be dual c/way - Was looking for a roundabout at end of dual - was then looking for left then. Hadn't noted the name of the street turning into (Stenson - actually saw it as Walbrook leading all the way to the destination). Didn't note any of the turnings passing along the road. After Stenson, went straight on to Walbrook - Mentions that a little confused at roundabout of Stenson and Princes - wasn't expecting a roundabout - so just continued in what thought was straight on direction, but not able to confirm that on correct road, so wasn't actually sure that on right road - never saw st name - decided then to pick up number of the turnings on either side, but still not sure (not able to relate these to position on map while driving - "map was a bit of a mess in this area") - was feeling concerned that had gone wrong - so was looking for somewhere to pull in and work out where she was. Actually stopped at Princes road roundabout - about to look at maps and then saw the pub - "very relieved". Had noted that destination was at roundabout beforehand, but forgot this and wasn't expecting to see it when stopped.

APPENDIX 4A

Relevant sections from final questionnaire

SECTION 1: Some details about yourself

1. How old are you?

[ ][ ] years

2. Are you male or female ? *Please circle the appropriate number*

Male	1
Female	2

3a. What type of vehicle do you normally drive ?

Make (e.g. Ford) ______________________________

Model (e.g. Mondeo 1.6) ______________________________

Year or registration letter (e.g. 90, G reg) ______________________________

for office use only [ ]

3b. Was this vehicle bought new or second hand ? *Please circle the appropriate number*

New	1
Second hand	2

3c. Who owns this vehicle ? *Please circle the appropriate number*

Yourself (or friend/ family member)	1
Company/ employer you work for	2
Hire/lease company	3

(10)

4. What is your occupation?

____

Continued.......

SECTION 2: Unfamiliar journeys

This section refers to **Unfamiliar Journeys** - these are journeys in which you need some advice/information before setting off on the journey and/or during the journey

Questions 11 to 13 refer to the reasons why you make unfamiliar journeys. Please circle the appropriate number for each question.

11. How frequently do you make an **unfamiliar journey** as part of your work or business ?

2 or more times a week	About once a week	2-3 times a month	About once a month	About once every 2-6 months	About once a year	Never or very seldom
1	2	3	4	5	6	7

12. How frequently do you make an **unfamiliar journey** for routine non-work purposes (e.g. shopping, personal business, school runs) ?

2 or more times a week	About once a week	2-3 times a month	About once a month	About once every 2-6 months	About once a year	Never or very seldom
1	2	3	4	5	6	7

13. How frequently do you make an **unfamiliar journey** for leisure purposes (e.g. holidays, day trips) ?

2 or more times a week	About once a week	2-3 times a month	About once a month	About once every 2-6 months	About once a year	Never or very seldom
1	2	3	4	5	6	7

(31)

Continued.......

Questions 26 to 30 below concern your opinions as regards published maps.

26. How easy do you find it to locate a particular street name (e.g. Park Drive, Empress Way) on a published map?

Very easy								Very difficult
1	2	3	4	5	6	7	8	9

27. How easy do you find it to plan a route using a published map?

Very easy								Very difficult
1	2	3	4	5	6	7	8	9

28. How easy do you find it to establish your current location using a published map?

Very easy								Very difficult
1	2	3	4	5	6	7	8	9

29. Would you look at a published map out of general interest?

Yes	1
No	2

30. How much do you like reading published maps to find your way?

Like a lot								Do not like at all
1	2	3	4	5	6	7	8	9

(48)

Continued.......

SECTION 7: Navigation Information that you use to find your way

Imagine you are driving on unfamiliar dual carriageways and motorways and trying to find your way. Imagine also that you are using the navigational aid/s that you usually use (e.g. published maps, written instructions, sketched maps, etc.).

Question 52 below concerns how useful you think different types of navigation information (e.g. landmarks, junction layout, road numbers, street/road names etc.) are at helping you to find your way. NB Information that is useful will be **available** to help you, and will also be **effective** in allowing you to find your way.

52. When travelling on dual carriageways and motorways, how useful are the following types of navigation information in helping you to find your way?

Please circle the appropriate numbers for a-i below

	Very Useful								Useless
a) Road numbers (e.g. follow the A58)	1	2	3	4	5	6	7	8	9
b) Place names (e.g. follow signs for Hull)	1	2	3	4	5	6	7	8	9
c) Junction numbers (e.g. exit at junction 23)	1	2	3	4	5	6	7	8	9
d) Street/road names (e.g. turn left into Park Drive, follow the Brentwood road)	1	2	3	4	5	6	7	8	9
e) Landmarks on the route (e.g. turn left at traffic lights, straight on past petrol station)	1	2	3	4	5	6	7	8	9
f) Road/junction layouts (e.g. turn right at crossroads, road bends left)	1	2	3	4	5	6	7	8	9
g) Long distances (e.g. follow road for 3 miles)	1	2	3	4	5	6	7	8	9
h) Short distances (e.g. turn right in 300 yards)	1	2	3	4	5	6	7	8	9
i) Compass directions (e.g. head Northwards)	1	2	3	4	5	6	7	8	9
Other (please specify) ______	1	2	3	4	5	6	7	8	9

(32)

Continued......

Imagine now that you are driving on unfamiliar single carriageway roads (out of towns and cities) and trying to find your way. Imagine also that you are using the navigational aid/s that you usually use (e.g. published maps, written instructions, sketched maps, etc.).

Question 53 below concerns how useful you think different types of navigation information (e.g. landmarks, junction layout, road numbers, street/road names etc.) are at helping you to find your way. NB Information that is useful will be **available** to help you, and will also be **effective** in allowing you to find your way.

53. When travelling on single carriageway roads (out of towns and cities), how useful are the following types of navigation information in helping you to find your way?

Please circle the appropriate numbers for a-h below

	Very Useful								Useless
a) Road numbers (e.g. follow the A58)	1	2	3	4	5	6	7	8	9
b) Place names (e.g. follow signs for Hull)	1	2	3	4	5	6	7	8	9
c) Street/road names (e.g. turn left into Park Drive, follow the Brentwood road)	1	2	3	4	5	6	7	8	9
d) Landmarks on the route (e.g. turn left at traffic lights, straight on past petrol station)	1	2	3	4	5	6	7	8	9
e) Road/junction layouts (e.g. turn right at crossroads, road bends left)	1	2	3	4	5	6	7	8	9
f) Long distances (e.g. follow road for 3 miles)	1	2	3	4	5	6	7	8	9
g) Short distances (e.g. turn right in 300 yards)	1	2	3	4	5	6	7	8	9
h) Compass directions (e.g. head Northwards)	1	2	3	4	5	6	7	8	9
Other (please specify) ______	1	2	3	4	5	6	7	8	9

(41)

Continued.......

SECTION 8: Ways of giving and receiving directions

Imagine now that you are travelling on an unfamiliar journey using directions to find your way (the directions may be your own or provided by others). Imagine that these directions contain a number of landmarks (e.g. traffic lights, petrol station, etc.). Question 57 below concerns how good or poor you feel, based on your experience, that different landmarks are in helping you find your way. NB We are **not** intersted in how often these landmarks occur on the roads, just how effective they are when they are present.

57. In your experience, how good are the following landmarks at helping you find your way?

Please circle the appropriate numbers from a-u below

	Very Good								Very Poor
a) Traffic lights	1	2	3	4	5	6	7	8	9
b) Repairs garage	1	2	3	4	5	6	7	8	9
c) Pelican crossing	1	2	3	4	5	6	7	8	9
d) Dip in road	1	2	3	4	5	6	7	8	9
e) Bridge over road	1	2	3	4	5	6	7	8	9
f) Railway line	1	2	3	4	5	6	7	8	9
g) Hump-backed bridge	1	2	3	4	5	6	7	8	9
h) River	1	2	3	4	5	6	7	8	9
i) Church	1	2	3	4	5	6	7	8	9
j) Bus stop	1	2	3	4	5	6	7	8	9
k) Petrol station	1	2	3	4	5	6	7	8	9
l) Wood/Forest	1	2	3	4	5	6	7	8	9
m) Railway station	1	2	3	4	5	6	7	8	9
n) Bend in road	1	2	3	4	5	6	7	8	9
o) Named Superstore	1	2	3	4	5	6	7	8	9
p) Street name signs	1	2	3	4	5	6	7	8	9
q) Multi-storey car park	1	2	3	4	5	6	7	8	9
r) Named shop/restaurant	1	2	3	4	5	6	7	8	9
s) Monument	1	2	3	4	5	6	7	8	9
t) Brow of a hill	1	2	3	4	5	6	7	8	9
u) Advertising hoarding	1	2	3	4	5	6	7	8	9

(22)

Continued.......

57. (Continued)... In your experience, how good are the following landmarks at helping you find your way?

Please circle the appropriate numbers from v-ac below

	Very Good								Very Poor
v) Telephone box ______	1	2	3	4	5	6	7	8	9
w) Cinema ______	1	2	3	4	5	6	7	8	9
x) Bus/coach station ______	1	2	3	4	5	6	7	8	9
y) School ______	1	2	3	4	5	6	7	8	9
z) Post box ______	1	2	3	4	5	6	7	8	9
aa) Named Factory ______	1	2	3	4	5	6	7	8	9
ab) Public House ______	1	2	3	4	5	6	7	8	9
ac) Park ______	1	2	3	4	5	6	7	8	9

(30)

58. In your experience, are there any other landmarks you have found useful ?

______

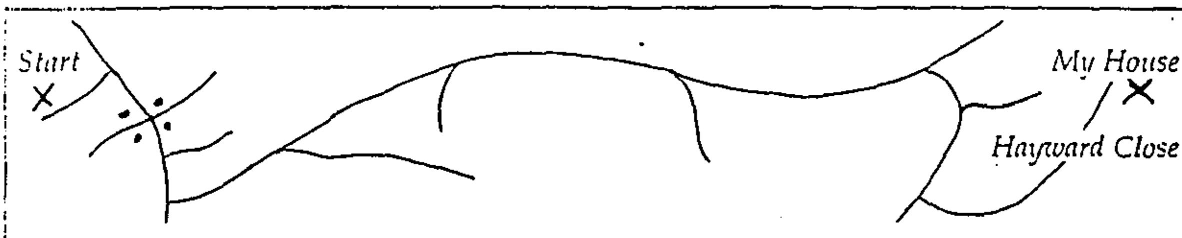
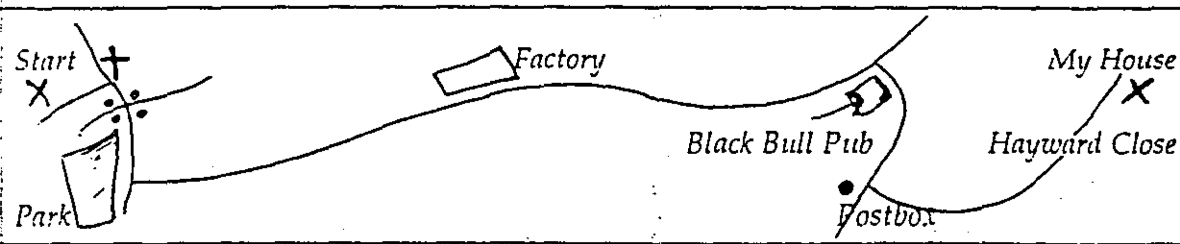
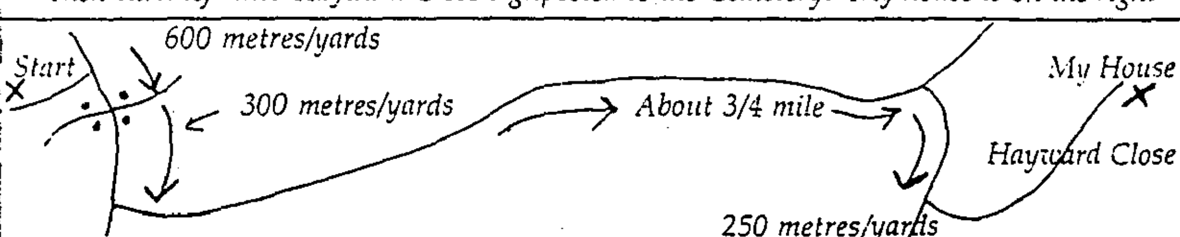
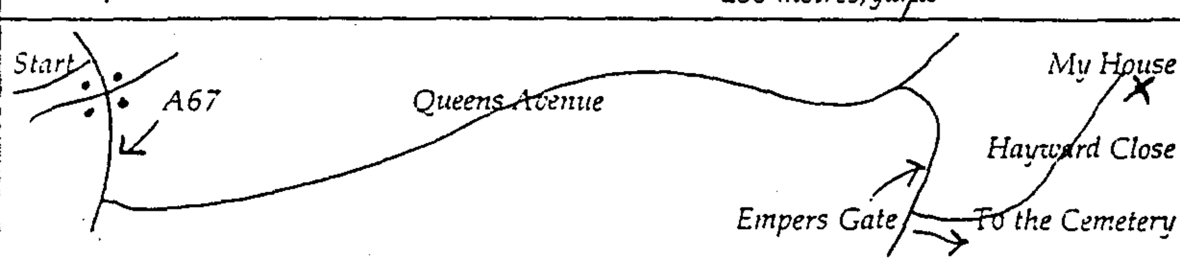
______

______

______

Continued.......

59. The following are different ways in which you could be given paper directions by someone on how to reach a destination. Please rank them in order of preference, from 1 to 8 (where 1 is the most preferred and 8 is the least preferred) - explain your choices on the next page. Please do **not** use equal ranks.

a)	• *Turn right at the end of the road by the church* • *Then drive past the crossroads (with traffic lights) and then turn left at a park* • *Follow the road for a while past a factory and then turn right at the Black Bull pub* • *Then turn left into Hayward Close by a postbox. My house is on the right*	
b)		
c)	• *Turn right at the end of the road* • *Then drive for about 600 metres/yards until you go past the crossroads (with traffic lights) and 300 metres/yards after this turn left* • *Follow the road for a while (about 3/4 miles) and then turn right* • *Then after 250 metres/yards turn left into Hayward Close. My house is on the right*	
d)	• *Take next turning right at the end of the road* • *Then drive past the crossroads (with traffic lights) and then take second turning left* • *Follow the road for a while and take the fourth turning on the right after the left-hand bend* • *Then take second left into Hayward Close.. My house is on the right*	
e)		
f)	• *Turn right at the end of the road onto the main A67* • *Then drive past the crossroads (with traffic lights) and then turn left onto Queens Avenue* • *Follow this road for a while and then turn right onto Empers Gate* • *Then turn left into Hayward Close signposted to the Cemetery. My house is on the right*	
g)		
h)		

(38)

Continued.......

Please explain your choices for question 59 below....

APPENDIX 4B

Full list of subjects' comments

CODING

IL - Instructions with Landmarks
IR - Instructions with Road layout
ID - Instructions with Distance
IS - Instructions with road/street Signs

SL - Sketches with Landmarks
SR - Sketches with Road layout
SD - Sketches with Distance
SS - Sketches with road/street Signs

Subject 1
SR - If something goes wrong have nothing to go on
IS, SS - Like having st names to relate to - if you are lost have something to ask about; Would like to have distances as well as st names though
Subject 2
People don't usually put in enough detail in their sketches and they can be misleading
SL - Would be ideal if combined with instructions with street names
Subject 3
Written instructions stay in memory
Sketched routes - sometimes can be difficult to work out the left and right turns
IL - left and right instructions are not confused
ID - Written instructions stay in memory - left and right instructions are not confused
IS, SS - Street names can be very helpful
Subject 4
SL - Simple and direct
Subject 5
IL, IR, IS - This form of instructions is easy to follow
SR - Maps with no markings on can be difficult to read and interpret
ID, IR, IS - Excessive written directions, or ones with not enough information are hard to follow whilst driving and require frequent checking to follow them correctly
ID, SD - Distances are not always accurate, either in terms of directions given by others or in estimate made by driver
SL - Easy to follow - just look for the next landmark
Subject 6
Would find it more difficult to have to read any of the instructions, as I would not have the overall plan in my head
IL - Excessive written directions, are hard to follow whilst driving and require frequent checking to follow them correctly
SL - The maps with landmarks I found very reassuring - would know if overshot the junction
SD - I find being given the distances reassurring - would know I had not overshot the junction
Subject 7
IS - Good because gives details of specific road numbers, street names etc.
SD - Is good because it gives an idea of distances between turnings, etc.
Subject 8
SL, SS - I find it easier to use maps with specific landmarks or with road numbers or names; Also, find it quick to refer to on the move - do not like to stop to navigate
Subject 9
IS, SS - Gives the clearest directions
Subject 10
Sketch maps can be more quickly referenced
IL, SL, IS, SS - Find landmarks and street names quite useful while moving in a built up area
Subject 11
I prefer to follow written instructions, preferably my own - I find it easier than map reading

Map reading can be difficult, especially if the map is out of date
ID, SD - I do not like to be told distances as I cannot visualise them and therefore experience crisis of confidence

Subject 12

IS - Simple instructions with street names - able to absorb in chunks - i.e. split journey into 4 parts

Subject 13

IL - Directions very unspecific - very vague
SR - Provides no road names or numbers
ID - I find it very hard to judge distances
IR - These instructions would be very confusing
SL - Now landmarks bring the area to life!
IS - Provides road numbers and signs to area, e.g. cemetry
SD - Very confusing - no road markings
SS - A little easier to understand - a mixture of road numbers and landmarks and road names

Subject 14

IL- Choosing because of landmarks in text form
SR, SS - Provides very little information
ID - Don't like distance text
IR -Choosing because of 1st, 2nd left/right
SL - Choosing because of landmarks in sketch form
IS - Choosing because of street and road names
SD - Is fairly clear, but provides no landmarks, just distance

Subject 15

I only need to read written instructions and I can memorise them quite easily; I find it more difficult (than with instructions) to memorise information with maps, probably because I'm used to written instructions

Subject 16

SR - The simplist is preferred - this gives clear uncluttered information
ID, SD - Any measurement confuses things

Subject 17

IL - Would get lost at the park
SR - Can recognise turnings to follow
ID, IS - Provides too many instructions
IR - Quick brief instructions to read whilst driving - mainly memorised from reading beforehand
SL - Has distinctive landmarks
SD - Marking shorter distances helpful
SS - Providing the length of Queens Ave is not useful

Subject 18

IL - lacks clarity
SR - Is much too vague
ID - Too long winded
IR - Is concise, explict and simple (almost as much as instructions with street names)
SL - Is the clearest of the sketch maps
IS - Is concise, explict and simple
SD - Is almost as clear as the sketch with landmarks
SS - lacks detail

Subject 19

IR - would be ideal if combined with sketch with landmarks

Subject 20

SL - Simple route easily shown with sufficient symbols to follow to destination. A lot of unnecessary detail has been omitted to save confusion

Subject 21

I have an aversion to drawings
IL - Instructions precise and the way I like to read them
SR, SL - Do not like vague drawings
ID - Instructions clear
ID - too many measured instructions, e.g. metres and miles
IR - concise instructions
IS - Ok, but don't like A67

Subject 22

IL - straightforward, not waffled by unncessary detail
SR - Far too vague, no attention to detail
ID, SD - hard to judge road lengths when driving

IR - do not want to spend unneccessary time counting my turnings
SL - Straightforward - uses features (e.g. pub) as an aid
IS - Straightforward using street names; although signs may not be readily visible
SS - this map may get you lost
Subject 23
All the instructions would be difficult to follow when driving
SR - could do with more road names
SL - Easy to look at - clear drawing
SD - too much information
SS - easy to look at - clear drawing
Subject 24
I prefer to look at map rather than to read instructions; I do not like to prepare a map myself
Subject 25
IL - very clear directions
SL, SS - very clear sketch map
Subject 26
SL - I like to follow a drawn map which is quite detailed showing side roads and dead ends and any prominent buildings (e.g. churchs, pubs)
Subject 27
IL - fairly identifiable directions
IL, IR - not as clear or concise as instructions with street names
SR - Not sufficient identification of road numbers/landmarks
ID - distictively vague
SL - reasonably easy to identify route to take
IS - clear and concise - street names are readily identified
SD - Somewhat vague and if distances were not correct mistakes could occur
Subject 28
I prefer visual to written aids
IL, SL - I need landmarks
ID - a set of written instructions with distances is very useful, although distances are deceptive as they relate to speed
Subject 29
IL - directions with landmarks are good
SL - a drawn map with landmarks is easy to follow while driving
SD - A map with distances is very useful
Subject 30
Graphical instructions are more difficult to follow on the move and are more difficult to check off each turning on change of direction
IS - I prefer written directions with road names and numbers which enables me to cross check the turnings
Subject 31
IS, SS - provides clear identification (by number and name)
Subject 32
I prefer being given instructions verbally
IL - straightforward and easy to understand
SR - I do not find this sketch map so easy to follow
ID, SD - I can never really judge 600m, 250m etc.
IR - prefer pointers, e.g. postbox, church etc.
SL - I find this sketch much easier to follow
IS - I find these instructions easy to follow
SS - I can follow this map easier than having to judge distances
Subject 33
IL, IR - not enough information
SR - no information at all
SL - Factories and pubs make good landmarks
IS - clear instructions with road names
SD - ok, but distances are hard to guess
SS - road numbers and names cannot be confused
Subject 34
IL - could have more information
SR - not enough information
ID - too much information to bother about
IR - no road numbers

SL - this sketch is ok
IS - this route is very good
SD - too sketchy
SS - this map is ok
Subject 35
IL - not as explicit as instructions with distances
SR - poor map
ID - good directions giving distances (i.e. metres and yards)
IR, IS - directions not quite so detailed
SL - reasonably good directioned map
SD - map nearly as good as sketch with road numbers; does not show road numbers
SS - good explanatory map giving road number (A67)
Subject 36
No time to study detailed words - road concentration is essential
SL - diagram with occassional landmark is easy to refer to, i.e. minimal road concentration interuption-this comments assumes landmarks are clearly identifiable of course
Subject 37
I prefer text to maps - easier to locate where you are up to
IL, SL - specific landmarks are better than distances
ID, SD - unable to estimate short distances when driving
Subject 38
ID, SD - unless somebody is good at judging distances these are useless in any system designed to help people find their way in unfamiliar surroundings
IR, SL, IS - there are a number of identifiable objects on the route which can be seen whilst driving
Subject 39
SS - is the best for me as it's uncluttered but very accurate. Also very quick to read when on road
Subject 40
SR - too barren and devoid of detail/scale
ID - 2nd choice has a different mix but again with specifics
IR - has too many lefts/rights/numbers
IS - my first choice - has a good mix of different identifiers. This gives you different options of what to look for
Subject 41
Plans can be more helpful than instructions - Maps can be untrsutworthy and sometimes lengths on map bear little relationship to lengths on the ground
IL, SL - landmarks are more easily located than street names
SR, IR - easy to count the number of left/right turns than follow a street until it ends or judge distances
ID, SD - difficult to judge distances, particularly if lengthy
Subject 42
IL - no names for church, factory or road numbers
SR, ID, IR, SL - no road names
IS - provides more information than others
SD - no road names or buildings
Subject 43
IL - gave little relevant information
SR - gave little relevant information
IS, SS - gave actual road names, so I would know I was on the correct roads
Subject 44
IR - is clutterered and needs constant reference to achieve the required effect
IS - is clear and concise and allows easy reference
IS - would be ideal if combined with sketch with landmarks and sketch with street names
Subject 45
IL, IR - is clear and concise
SR - too little information is useless
IS - prefer to follow directions that are clear and concise reducing the possibility of making mistakes
SD - too much detail is misleading
Subject 46
Most maps are better if detailed than just words alone as you can understand the directions quicker and more easily
IL, SL - landmarks are a good idea, but can be misleading if have too many of the same nature in a short area
SD - is best because it includes a map and specific distances

Subject 47
IL, IS - provides short instructions. Easy to remember one at a time
SR - not enough information for unfamiliar route
ID - too wordy. Would have to take eyes off the road for too long - dangerous
IR - too many lefts and rights. What a muddle!
SL - easy to follow if you're driving along - obvious landmarks
SD - provides no road numbers/names. Would be unsure if I was on the right road
SS - includes road names/numbers
Subject 48
IL, SR - useless - I would now have to go to a map of-my own
ID - clear (similar to instructions with street names and with road layout)
IR - too much writing
SL - might be more difficult if long distances between junctions
IS - clear (similar to instructions with distances and with road layout)
SD - would modify it - too much to take in on sight
SS - was brief - straight to the point. It was clear and the necessary instructions were there
Subject 49
IL, SL - landmarks are misleading if have too many of the same nature in a short area
SR - is very unclear with no distances and no street names or milestones
ID - ranked high because gives distances between milestones
SL - has street names and pub/factory as milestones; would be better if had distances between milestones
SD - ranked high because gives distances between milestones
Subject 50
All the maps clearly state the starting point and destination making it fairly obvious to find 'my house'.
I very rarely draw a map myself when driving to unknown destination
All of the notes are less clear and probably easier to make mistakes with
SL - was the most straightforward
SD - the distances I thought were a little unneccessary
Subject 51
IL, ID, SD - would be difficult and frustrating since leaves grey areas (e.g. existing streets not mentioned)
IR, IS - accurately describes the route to follow and highlights identifiable streets
Subject 52
IL - are brief instructions which can memorise easily
SR - very little information
ID - is brief, concise and gives distances
IR - is brief and concise, but omits distances
SL - no distances or street names - park and factory vague
IS - no distances given which leads to errors
SD - straightforward plan with distances
SS - no distances making it difficult to find roads
Subject 53
SL - is simple sketch which can memorise easily
IS - are brief instructions which can memorise easily
Subject 54
Distrust sketched maps - mainly because of scale
IL, SL - if landmarks are missed they confuse the journey/mess up memory pictures
ID - prefer distance instructions
Subject 55
IL - good use of landmarks
SR - no information!
ID - no landmarks
IR - little use of street names/landmarks
SL - no need to know distances. Landmarks should be obvious
SD - clear map with distances and travel direction
SS - easy to follow street names
Subject 56
IL, IR - would be better if combined with map
SR - not enough road information
ID - provides distances
SL - slightly lacking in information
SS - almost as good as sketch with distances

Subject 57
I prefer instructions to a map if only one was available from somebody else - from experience maps are badly drawn. Best option is to have both map and written instructions
SR, IR - I like to have number of roads listed (e.g. 2nd left, 3rd right etc.)
SL - like to have local landmarks
Subject 58
Good instructions are better than poor maps
IL - landmarks are key if the route is difficult
ID, SD - distances mean nothing as concentrating on distance and direction is too difficult
SL - landmarks are key if the route is difficult; in urban situations where a published map would be too detailed to be useful the naming of landmarks avoids the need for complexity
IS - in urban situations where a published map would be too detailed to be useful the naming of streets avoids the need for complexity
Subject 59
IL, ID, IR - too confusing written instructions
SR - hopeless map
SL - this is my first choice and is the map you most write yourself and that people write for you (i.e. pub and street names, factory etc.)
IS - most understandable of the written instructions
SD - map has too many distances incorporated
SS - next best map (to one with landmarks)
Subject 60
ID - was easy to understand and gave names
SL - at a glance I could see the route with landmarks
SD - 1st choice was easy - at a glance I could see the route, road names and distances
SS - at a glance I could see the route with street names
Subject 61
IL, SL - easy to spot/ask for landmarks. Could be easy to recover if lost
SR - could be other exits which could be misleading
ID - could miss 1st left and right turn
IR - could miss left hand bend if not sharp
IS - looking for road signs on move not recommended. Bushes obscure signs, signs go mising etc.
SD - use of 'about' - not reliable instructions
SS - would not have much confidence if finding 1st left as not defined enough
Subject 62
IL - church not defined nor side of road for park
ID, SD - distance information is superfluous
SL - this sketch map gives me two key points/landmarks i) when to turn left (opposite park) ii) turn right by pub (black bull)
Subject 63
I find it easier to convert a visual image into real directions - distance is implied by scale
ID - distances in text are an easy way of checking on directions
SL - the most information is apparent when landmarks are included within a sketch
SD - adding actual distances to sketch is useful
SS - street names make route easy to follow and increase confidence
Subject 64
For all instructions - easy to put on post it note on steering wheel
IL - easy to read, clear written instructions
IL - would prefer to know main road numbers
SR - I'd get lost as there are no indicators to confirm that you are on the right road
ID - too much distance - difficult to judge
IR - a little vague
SL - would prefer more road information on this map
IS - easy to read, clear written instructions (like inclusion of main road A67)
SS - for a short distance this is ideal - road numbers and landmarks - simple, uncluttered diagram
Subject 65
IL - relates to recognisable landmarks; but is harder to visualise than sketch with landmarks
SR - allows navigation by counting off streets passed, but may not show the correct number of turnings
ID - it would be easy to misjudge distances, plus doesn't even have the advantage of a map to visualise the problem
IR - would be easy to remember
IR - is hard to visualise

SL - provides a mix of landmarks and street names - landmarks are reassurring that correct turn has been taken
IS - provides 'landmarks' in the form of street names
IS - street names can be hard to spot
SD - doesn't contain enough information - it would be easy to misjudge distances
SS - street names can be hard to spot

Subject 66

I prefer maps as long as detail is sufficient
IR - short instructions with relative rather than absolute information is ok

Subject 67

I prefer text in general
IL, SL - require use of larger landmarks
ID, SD - indication of distance quite useful

Subject 68

IL - clear written instructions
SR - could easily miss a turn
ID, SD - don't like distance instructions; I find it hard to judge distances
IR - turns could be anywhere
SL - fairly clear map
IS - not bad
SS - not as good a map as one with landmarks

Subject 69

IL, IS - basic text - gives enough information without too much detail
SR - very poor line drawing
ID - basic text giving more detail
SL, SD - basic information - not confusing - easy to follow
SS - easy line drawing - not too much information

Subject 70

I prefer to read a written list, rather than look at a map - maps can be difficult to read
IL, IS, SL, SS - I prefer those instructions/maps that give more details, e.g. landmarks or street names which I can remember easily

Subject 71

IL - good brief instructions; gives local landmarks first and street names towards end of journey
SR - too brief (no landmarks)
ID, SD - do not like giving distances as I am not very accurate
IR - good brief instructions - gives slightly more detail than instructions with landmarks
SL - shows where turnings are and includes some street names
IS - good brief instructions giving street names
IS - street names can sometimes be hidden by parked vehicles
SS - does not show landmarks

Subject 72

SL - was my first choice as it had more details than other maps (e.g. factory shown)
SD - didn't like maps with approximate distances

Subject 73

IL, SR - not enough information
ID - fairly reasonable
ID - I am not very good at judging distances
IR - needs more street names then would be ok to follow
SL - not enough road/street signs etc.
IS - chose this as follow road/street names when travelling
SD - map with distances better to follow than instructions
SD - needs more street names then would be ok to follow
SS - this map would be easy to follow

Subject 74

IL - reasonable
SR, IR - simple to memorise if in traffic
ID - judging distances whilst driving 'not on'
SL - likely to be a nuisance to others dearching for landmarks, i.e. crawling
IS - if road number missing would lead to some confusion
SD - much indigestion over distances - ughh
SS - street names occassionally hidden from view

Subject 75

IL - not clear enough with regard to distances etc.

SR - not helpful
ID - informative - clear description
IR - very confusing
SL - fairly clear
SL - could mistake turnings
IS - somewhat inprecise
SD, SS - easy to follow whilst driving
Subject 76
Sketches far easier to read
IL - could not check at a glance
SR - no landmarks to confirm route
ID - too much imformation in written notes
IR - a bit vague with no set distances or landmarks
SL - clear easily read map with just enough information
IS - clear instructions, but you'd have to stop to check them
SD - not so good as you'd have to estimate distances
SS - clear map, but harder to read than one with landmarks
Subject 77
Instructions written down are easy to follow, short and to the point
ID, SD - involves using distances which would be helpful
SL - this map is easy to read as landmarks are quite large and should be easy to see
Subject 78
SL - I can see the landscape in my 'minds eye', because of the geographical features presented on this map
Subject 79
IL, SL - uses obvious highly noticeable landmarks.
Prefer to know I'm on course because I've just passed pub (IL, SL), rather than straining my neck and eyes looking for street name signs (IS, SS)
ID, SD - disliked reference to metres
IS, SS - street name references would normally be ok
Subject 80
ID, SD - the addition of distances is not needed - the map would show this anyway
SL - would be ideal if combined with instructions with street names
Subject 81
SL - maps with landmarks are simple to understand and reference when driving and can be committed to memory
Subject 82
SL - parks, pubs etc are good at alerting you to your turning
SS - road names can be checked
Subject 83
No comment
Subject 84
No comment
Subject 85
No comment
Subject 86
I prefer visual to written instructions
IL, SL - I prefer landmarks to distances; I like to see a pub mentioned as more people seem to know where a pub is, rather than other buildings
IS - I choose this one first because when you have the road names in this format you know straight away when you have taken a wrong turning and therefore you can correct yourself when you go wrong
Subject 87
IL, SL - peoples ideas of a good landmark can differ greatly. So therefore, could think following route ok, but in reality not and by time realise you are lost
ID, SD - peoples approximations of distances can differ greatly.
Subject 88
I would find it easier to follow a set of written instructions rather than the maps - a small sketch much more of an aid if it came with a set of written instructions
SR, IR - rather than looking out for a particular road I would prefer to be told that was 3rd left etc.
Subject 89
IL - good - uses landmarks
SR - no guide to highlight/identify turns
ID, SD - not easy to judge distance

IR - no guidance as to what constitutes a turn
SL - distinctive, visual - uses landmarks
IS - like to be given road names
SS - distinctive, visual, although less use of landmarks than I would like
Subject 90
Diagram/pictorial is easier to understand
IL - distictive landmarks to find when I need to turn
SR - provides no landmarks
ID - provides specific directions with distances
IR - provides specific directions with numerics
SL - clear landmarks, e.g. park, factory, pub
IS - provides specific directions with road/street names
SD - clear landmarks and distances marked
SS - clear landmarks and road names given
Subject 91
SR - I'd almost certainly miss a turning somewhere
ID - would never be certain I was on course
IR - I'd almost certainly get lost, directions not at all specific
SL - clearly shows where to turn - very little ambiguity
IS - would have to keep reading and checking directions
SD - can be difficult to judge the longer distances
SS - little information to assure me that on route
Subject 92
An illustrated sketch map is preferred to written instructions
IL, SL - landmarks are more useful than distances alone
SL - was most preferred as it was a map and at each of the junctions there is a prominent landmark
IS, SS - street names are more useful than distances alone
Subject 93
ID - clearest written directions
SL - map with the clearest directions
Subject 94
IL, SR, ID - not enough information
IR, SL - lacking in road names and numbers
IS - good directions
SD - metres/yards get in the way of important landmarks
SS - needs landmarks
Subject 95
I prefer visual aids (maps can be glanced at) - Directions have to be read
SR - the map with no markings would be useless to me; I would always doubt that I had the wrong turn etc. if there are no distinct/obvious landmarks
ID - the instructions with distances would be useless to me. I would always doubt that I had the wrong turn etc. if there are no distinct/obvious landmarks
SS - this is the most detailed with names of roads etc. Road names/numbers are the most simple to follow
Subject 96
In general, I don't like written instructions and prefer maps
IL, SL - provides landmarks
SR - the basics are there
ID - provides distances
IR - too obscure
IS - provides road numbers and names
SD - is easy to read
SS - is simplist and easy to read
Subject 97
Maps are easier to see and understand than written instructions
IL, SL - park/factory/pub easier to see on the ground than street names
SR - prefer some pointer (landmark or street name) rather than just roads
ID, SD - distances too difficult to estimate
IR - prefer some pointer (landmark or street name) rather than just roads
Subject 98
SL - was the most constructive directions. Clear sketch map with major landmarks indicated, Would be able to sort out rights and lefts for myself
IS - short and decisive instructions

Subject 99
I find visual aids superior to text, especially when moving or stopping quickly to have a look
SL - I prefer this as references easy to see from car and refer to when asking for help - the map is clear
Subject 100
SL, IS - provides specific information (i.e. landmarks/street names)
SS - provides maximum information and gives specific information (i.e. road numbers)
Subject 101
SL - looked clearer than the other maps and when needed shows the street name to look out for
IR - also clear, counting streets is a good idea (i.e. 2nd left)
SS - easy to follow if street names are visible
IL - as for IR, but not as clear
IS - similar to IL
ID and SD - my ability to estimate distances is poor so these would be unhelpful
SR - unclear, risks being incomplete
Subject 102
I like my instructions to be written down for me with as much information about landmarks on as possible. If the instructions are drawn I also like to see landmarks not so much distances, e.g. 350 metres
Subject 103
Because it (IS) uses road numbers and street names and not distances it is easier to follow written instructions than drawn maps in my opinion
Subject 104
I find it easier to follow written instructions rather than a map when glancing down whilst driving
Subject 105
SR - It seemed easy enough to follow for quickness
Subject 106
I prefer maps. Landmarks are easier to spot than judging how far 600 yds is for instance. Written instructions are clearer is they say 2nd left into rather than give just road name as you have two forms of detection and donlt have to slow down at every junction in search of a road name.
Subject 107
It was easy to follow with the landmarks, and well identifiable landmarks, clearly labelled. IR is the type of instructions that I would normally use, i.e. 2nd left is easier to find than a specific road name as road names are not always visible and cause you to slow down a lot when trying to find them. Putting distances down on maps or instructions only serves to confuse me
Subject 108
No comment
Subject 109
Prefer diagrams to text. Road names are good as these will be signed and can be seen easily. Other landmarks are good, but may not be seen as easily as signs. Distances are difficult to judge whilst driving - unless mileometer is used (need to remember).
Subject 110
IL - choice 1 - written instructions with plenty of landmarks
ID - chove 2 - written instructions with distances marked
IR - choice 3 - written directions with turnings clearly indicated
IS - choice 4 - poor written directions, but better than a map
Sketches - choices 5, 6, 7, 8 - judged on quality and detail of map. Written instriuctions are always easier to follow, but if you have to have a handrawn map, the more instructions the better!
Subject 111
SL - although it is only a basic outlined map and gives no actual distances, it has easy to spot landmarks which are unlikely to be obscured as road signs can be
ID - distances are useless to me
Others - verbal directions are fine but a short map is easier to refer to on the move without the need for retention of all the information
Subject 112
Picture better than words
Pictures - SL - is simple to visualise en route; SS - road numbers and street names easy to spot en-route; SD, SR - both are pretty poor, when people draw they tend to use more info than this
Words - IS, IL - street names easier to pick out of text than places or things. Hence IS better than IL. IR and ID useless, probaly written by someone that has never had to follow directions!
Subject 113
SL - has most landmarks - route is memorable
SD - distances and navigation
SR - shows side roads to aid turning points

SS - some landmarks and one route
IL - uncluttered directions
IS - unclutter directions
ID - too many words to take in whilst driving
IR - too imprecise
Subject 114
IS - is precise even if you take the wrong route - you can reposition
SD - precise if slow and make no mistakes
ID - precise with names, therefore can reposition
IR - precise but counting etc. cannot reposition
SS - vague no distances, no names items left out
SR - vague with no names or distances
IL - vague enough to miss landmarks - no supporting details
SL - vague - items left out - easy to go on the wrong route - no distances
Subject 115
IL - conveys information in the way which appeals to me
SL - is as good but in map form
IS - is preferred format but uses street names instead of landmarks
SS - is reasonable but not preferred
SD - I have little confidence in
IR - I have little confidence in
ID - I have no confidence in
SR - I have no confidence in
Subject 116
SL - easy to look up directions and milestones
SS - road names and directions easy to follow
SD - map with distances easy to follow
SR - map with all roads easy to follow
IS - simple written instructions
ID - just looking for a set of instructions that are easy and concise to follow
Subject 117
I aways find that a written route can be less confusing than a drawn one. Also distances can be difficult to judge especially short distances
Subject 118
IL - not enough street names used
SR - not enought information on any aspect
ID - totally useless to me. I cannot judge distances very well
IR - very good but just needs the street names
SL - good but again street names needed
IS - excellent
SD - answer as for ID
SS - ok
Subject 119
IL - text can be partly memorised during journey without needing to take eyes off road- can be used to memorise forward locations by easy visual locations
SL - if combined with no.1 enables a global view of journey and partly memorised text in 1.
Subject 120
Any map ties in with the situation you face when driving. Lists of situations do not. Equally - road names, named pubs/post boxes etc. give precise feedback that you are where you should be. Distances, turn 2nd left are NOT precise and are invariably doen to judgement
Subject 121
SD - this can be followed on the move
Subject 122
SS - I found useful because I like using names of roads like A67 and Queens Avenue. They make the route very clear to me.
Subject 123
Easier to look at sketch than read text. sketch with landmark at turn/junction is preferable. Scale or idea of distance between turns is desirable. Specific instructions in text form with distances is preferable to vague suggestions. To drive and receive a visual direction indication at same time, must ensure that input in a quick clear snapshot, totally unambiguous.

Subject 124
If driving along and in a hurry I especially don't have time to read directions. I like to look at a map and point out right away where (1) arrows are pointed to the specific place (2) distinguished landmarks that stand out on the map.
Subject 125
I prefer listed instructions from the other party rather than a map. I chose IL as my no.1 due to simplistic landmarks rather than phsyical descriptions, e.g. 600 yds etc. For the maps I felt that SL was by far the most simplistic and again used landmarks to help with the directions. SS was a reasonable map and had the A67 and road names as the main clues rather than 3/4mile and 250 metres etc. As in example SD, SR was a bit too simple with no landmarks or street names etc.
Subject 126
IS - is the most easiest to write
SS - corresponds with IS
SL - seems ok
SD - looks ok
IL, SR, ID, IR - seems and looks ok
Subject 127
IS - this seems clear because it tells you the road names required
SS - looks like a clear diagram indicating route and road names
IR - seems fairly clear but no road names
SL- a clear diagram showing landmarks, but I like road names too
IL - again seems quit clear
SD - I find it hard to follow exactly where to turn when refers to yards/metres/parts of miles
ID - ditto
SR - this diagram doesn't give enough information and none of them give the house number or name!
Subject 128
I prefer maps/plans. Prefer landmarks to reassure that I am going in the right direction. If no landmarks then road names. If written text then I prefer to be told when to turn, e.g. 2nd left. Short distances help between turns, but if long distances are given then they become less effective (as they provide less reassurance)
Subject 129
SD - is my preferred option.- visual map showing a very clear route with directional arrows.
SL, SS, SR - all preferred because give maps to follow
IS - wriiten instructions with the road names which is useful when on a rural road
IR - ubclear when telling you to cross traffic lights
IL - very unclear and confusing
ID - don't like becsuse I find distances very hard to judge in the car
Subject 130
I found that there was not enough information on any directions. A compilation from all of these would possible be satisfactory
Subject 131
SL - it has landmarks all the way on your route and are able to follow it at a brief look when looking out for the place you are going to, rather than looking for street names all the while and reading where you have to go.
Subject 132
SD - clear - specific distances - easy to follow
SS - simple diagram - road highlighted
ID - clear precise instructions
IS - road highlighted, e.g. A67
SL - clear map with landmarks
IL - fairly clear instructions
SR - no scale - no landmarks
IR - no scale - no landmarks
Subject 133
SS - to me looks the best to follow because of roads marked, e.g. A67 and street names - less confusing driving along an unfamiliar route.
Subject 134
SL - very clear easy to see landmarks
ID - gives distances so if you go to far you know you gone wrong
SD - too much to take in - prefer text information with distance
IS - not enough detail - could be looking all over
SS - ok, but could do with more detail
IR - ague

SR - not very detailed would have to study hard
IL - easy to miss post box

Subject 135

IR - my first choife would be easy to commit to memory and I like the idea of counting streets
IL - my second choice was close as it has all the landmarks
SS, SS - these two maps were incomplete, i.e. did not show all side roads or any landmarks

Subject 136

I need landmarks as well as distances to feel confident of finding the way. I prefer street or road names. I could drive past a post box and not notice it was there. I can't judge short distances so "turn right after 300 metres" means nothing to me. "take the 4th turning on right" is not good for me - I could count someones drive as a turning or miss one (I have done this!)

Subject 137

At a glance SS is first choice because I find road names easiest to follow. Then SL because landmarks are then easy to spot. The information from these two diagrams are easy to absorb. SR and SD are least favoured because they are too vague to follow. As for the written details I favoured IS as third choice as this gave a lot of details of road names and landmarks. IL, ID and IR did not define such clear details. SS is my favourite as it gives me the clearest details/

Subject 138

IL - I am used to instructions such as these
SR - map looks bare, but can easily be worked out
ID - I hate instructions with numbers in
IR - OK instructions
SL - maps ok, but I don't really like directions where you have to work out whether your car is facing North, south east or west.
IS - not enough information - could get easily lost as there are no landmarks
SD - boring
SS - is a boring map

Subject 139

Choice 8 (SR) was far too vague
Choice 1 (SL) had all the right landmarks on the skecth map to easily memorise, i.e. pub, post box etc.
Choice 2 (IL) was very similiar to 1 in word form
The choices with distances on them or written are harder because it means watching dashboard, seeing how far you have travelled - also not as safe as 1 and 2. Some other choices were vague in their language e.g. IR or my choice 4.

Subject 140

IS - easy to follow using street names
SD - shows distances and direction to take
SS - easy to follow diagram using just street names needed
IR - easy to follow directions
ID - easy to follow using distances
SL - easy to follow
IL - could miss certain references
SR - hardly any information

Subject 141

Gives their ideal....
Turn right at end of road. Go across the crossroads on the A67 and turn left onto Queens avenue for quite a way about 3/4 mile, turn right for about 250 yds then turn first left onto Haywood close. I live on Haywood close - marked.

Subject 142

All written descriptions below graphical as implied info. in graphical. Graphical gives additional 'spatial relationship' information. More detail the better. Numerical information difficult to verify/monitor. Large visible objects are better than road names as they are less easy to miss

Subject 143

SS - is my first choice because easy to look at - road names used
SL - also easy to look at while driving - landmarks
IL - explicit - uses landmarks
SD - easy to look at but distances mean little while driving
SR - prefer map to written instructions but not so easy as above
IR - explicit but not so easy to look at whilst driving
IS - not explicit enough
ID - very poor. Distances mean little

Subject 144

IS - road and street names are most important and is simple to follow and direct.

Subject 145
SL gives a precise route with landmarks - easy to follow
IL - concise directions with named landmarks
SD - too much unnecessary detail
SR - too vague
Subject 146
Written instructions easier to follow when driving. IL has no distances. SR - no landmarks. ID says it all.
Subject 147
Number 1 (IL) is the simplist with the landmarks. The drawing no. 8 (SR) has nothing between start and finish on route -too easy to get lost. No. 6 (IS) has follow for w hile which is no good for finding a destination.
Subject 148
IS - is the most preferred since when given street names etc. tend to know exactly where I am. Prefer written instructions than maps as maps drawn by other people tend to be very out of scale. Dislike being given distances e.g. 300 yards as find difficult to jusge when travelling at speed. SR is least preferred as no reference to street names or landmarks.
Subject 149
IL - past which factory -no house number
SR - needs more detail
ID - needs a very accurate odometer
IR - could do with more names and landmarks
SL - quite easy but lacking road names
IS - landmarks needed to warn you to turn into Empers Gate
SD - again accurate odometer needed
SS - needs more landmarks
Subject 150
My chouce was IL because I liked the way the details were written down, specifying where the turns were and what was nearby , e.g. church, traffic lights.
Subject 151
I find it easier to foloow detailed written instructions gicing road names and landmarks
Subject 152
IL - fairly easy to follow and stresses what to look for as well
Subject 153
No comment
Subject 154
IL - not easy or clear - description is vague
SR - no real lansmarks, numbers i.e. A58
ID - too hard to judge without markings
IR - clear to understand and remember
SL - no road names - dangerous to navigate
IS - good combination og road names and placs
SD - too graphic - not concise
SS - simple uncluttered - good balance of signs/names, road numbers
Subject 155
No comment
Subject 156
No comment
Subject 157
Directions very good. Directions well set out. Instructions not too bad. Map quite good. Instructions useful.
Subject 158
Easier with name of roads and streets
Subject 159
SS - chosen as roads names
Subject 160
IS - the best way of the directions given
Subject 161
IL - simple directions with easy landmarks to spot
Subject 162
They are in order to what I think I would understand the route. SL, IR, IS, SD, ID, SS, SR, IL

Subject 163
Maps are easier to read ata glance and to remember. Map SL had a combination of landmarks and street names. Written instructions IS also included road numbers
Subject 166
IR - was best as I could have remembered it without the paper
IL was vague about the park, otherwise ok
IS was ok but prefer to know how many turnings to Lor R
SR I would have remembered this as rights and lefts as would have not used map
SS - same comment as IS
SL -would have been where SR was if had all lefts and rights on it.
ID - would not be good for me - distances I dislike
SD - same comment as ID
I compared each one with each other one using a 1/0 answer and the totalled. Then tried to apply explanation.
Subject 167
IR - nice easy unambigous set of instructions
IL - again in list form but must be a bit more careful to identify landmarks
IS - list form but involving having to look at street names
SL - a pictorial representation with the important lanmarks when a change of direction is needed
SS - as before but street names have to be observed
ID - too many distances involved
SD - same as before
SR - no real hint as to which way to go before reaching Haywood close
Subject 168
I prefer to follow a sketch rather than notes
In a town it is easier to look for street names
Subject 169
I prefer a visual sketch and the more information on it the better without clutter. However, all the maps and the written instructions would be useful, and i think I would have found the house ok. If I had sketched a map I would have used SL plus "Queens Ave", plus approx. distances
Subject 170
When using diagrams/text I much prefer them to detail landmarks rather than street names or distances. The choices are based on which ones use this more effectively. I tend to prefer using maps (sketched) rather than text given a choice, however the map needs to have adequate detail as in SS but not as SR.
Subject 171
Graphical representation with easily recognisable landmarks is best. Enxt best some idea of distances instead of landmarks. Next best - road names. Bare map is better than text (quicker to interprete). Text with distances is slower, but accurate. Tect with no idea of distances is very slow to interprete, even with landmarks. Road names are harder to see than landmarks. Just counting turnings can lead to errors.
Subject 172
IS - choice 1 - use of road number and street names makes it easy to read and follow - san identify place if I should get lost.
IL - chouce 8 - no clear markings or identifiable landmarks if you get lost. Hard to read whether stationary or on the move.
Subject 173
Preferred the diagram with the distances, followed by the diagram with place names for references. The text which had the most information seemed the most comprehensive and the others followed in order of decreasing information given either in text or diagram.
Subject 174
IS - each road name marked
SL - Park and fActory on map
IR - turnings listed but no visual
IL - turnings not listed (1st, 2nd)
SS - no landmarks
SD - distances too vague
SR - not enough information
ID - not defined
Subject 175
SS - just the right information on the map
IS - just the right written information
IR - good written information
IL - fair written instructions

SL - reasonable map
ID - too much written information
SR - not enough information
SD - too much information
Subject 176
Sketch maps easier to picture and scale
Large landmarks easier than street names
SD - scale above is not helpful enough to confirm correct route
Subject 177
IS - that which provided the most unambiguous info.. Street names are infallable.
Left by park can be open to misinterpretation/confusion.
Distance is poor guide.
Bend/road info ok but not best in sketched form - like this info in published map.
Subject 178
SL - points of reference helpmuch more than having to read text.
SD - accurate distances help you feel you've gone too far, etc.
ID - ditto (but text is not as good, although easier to memorise).
SS - a bit vague on distances and scale.
SR - very vague and no real points of reference.
IS - no idea of length of journey and points of reference.
IL - very, very vague (e.g. follow the road for "a while?"), but at least points of reference pubs, etc.
IR - just awful.
Subject 179
For a relatively short journey such as this, the map (SR) shows all relevant information. It is easy to memorise: right at T; through TL; second left; fourth right; second right, etc. It is a simple journey.
Road names are not always easy to spot especially in heavy traffic or at night therefore SS and IS not ideal.
I'm hopeless at distances and therefore don't like SD and ID.
SL and IL are a bit vague - not all roads mentioned. I suppose a passer-by would know where the Black Bull was, though.
Subject 180
SL sufficient detail without being confusing.
Subject 181
IR provides clear uncomplicated instructions, i.e. first right, second left. Easy to follow, no need to spot road names, measure distance, etc.
SL - likewise, but has easy to follow picture with named landmarks. Combination of IR and SL the best.
As you go down the choices, the amount of detail either a) increases in complexity - measuring distances or left at a park (is this before or after park?) or b) reduces to nil value, e.g. SR (how far is journey, is it to scale, are any roads left out?)
A lot depends on how much information about roads you don't need is left out, e.g. IS would be useless if there were many possible turnings.
Subject 182
SL - Requiring least effort giving most useful information in minimum time. Have only to remember the name/type of key landmarks to look for. Don't have to watch for road names or distances. The map more easily shows juxtaposing of features.
Subject 183
My first choice (SL) is easily memorised and has good reference points. The verbal description (IL) is similar.
While I am a good judge of distance I think the descriptions that ignore the first left turn after the traffic lights are dangerous. I hope what has been described as roads off really are.
Subject 184
I preferred diagrammatic map with road names and streets ideally with distances. Least preferred were instructions but those which list street names are roads were preferred.
Subject 185
Assuming only roads are those which are marked SL contain the kind of landmarks and other information (approx distance, direction) I find useful. The others have variations which I find less useful, e.g. distance in yards, no road names, no landmarks.
Subject 186
Prefer visual clues/drawn routes.
Want plenty of information.
Road signs are best (I'm looking for them anyway).
Road side stuff next best.

Good written information better/easier to follow from stationery than poor visual information.

Subject 187

I prefer diagrams hence choices 1 to 3 (SL more closely resembles a diagram I would draw and the other two (SD and SS) are clear too). However, selection 8 (SR) is a very poor diagram.

With regard to written instructions selection 4 (IS) is a combination of road names and landmarks which I find useful too.

ID is ranked as 7th because I am not too fond of approximate short distances to travel. This can be quite difficult when travelling at any speed in a vehicle.

Subject 188

An informative well labelled map seems more immediately understandable.

Text can be good if it includes distance, names and landmarks.

Subject 189

IL - lots of landmarks, clear, easy to remember.

SL - again lots of landmarks to look out for and an idea of distances.

IS - lots of names, some landmarks maybe too much information

SS - pictorial, no landmarks, idea of distance.

ID - quite useful.

IR - few landmarks to look out for, vague ones mentioned.

SD - no road names or landmarks.

SR - no landmarks, road names, clues, etc.

Subject 190

SL - visually easy to follow and check at a glance whilst stopping e.g. at traffic lights (crossroads). All necessary landmarks are easy to see.

Subject 191

I chose SL because it indicated clearly where all the landmarks were and as it was in map form it was quicker for me to understand it.

IR I put last because it was far too vague.

Subject 192

I prefer written direction as I find it easier to remember them after reading them a couple of times. Diagrams are often confusing and I tend to need to keep referring to them as I can't remember what they look like. I normally convert diagrams into instructions in my head which takes longer and distracts me.

I chose IS because it gives me simple basic instructions. I also like IR and IL as they seem fairly simple and give me things to look out for.

Subject 193

SL - visual, lots of landmarks like pubs.

IL - uses easily identifiable landmarks, pubs, etc.

SS - visual, lots of road names not enough landmarks.

SR - visual but no road names/landmarks.

IS - too many road names usually hard to see.

SD - not enough landmarks, measurements don't mean much.

ID - confusing, can't measure "metres" whilst driving.

IR - confusing, too many rights and lefts.

Subject 194

Diagrams are always better. Landmarks very important followed by road names, then critical distances.

Subject 195

I chose SL as number 1 because the map is simple to follow.

I chose SD as number 2 because the map gives a little more information.

I chose SS as number 3 because the map gives a little more information.

I chose IS as number 4 because it is the simplest list to follow.

I chose IL as number 5 because it gives a little more information.

I chose SR as number 6 because the map gives just enough information.

I chose IR as number 7 because it lists information but requires looking at.

I chose ID as number 8 because lists of distances are difficult to relate to when in a strange area.

Subject 196

I prefer maps/diagrams to written instructions. Irrespective of whether the instructions are on a map/diagram or written instructions I like to see road names and particular landmarks. With respect to distances people quite often get these wrong I have found.

Subject 197

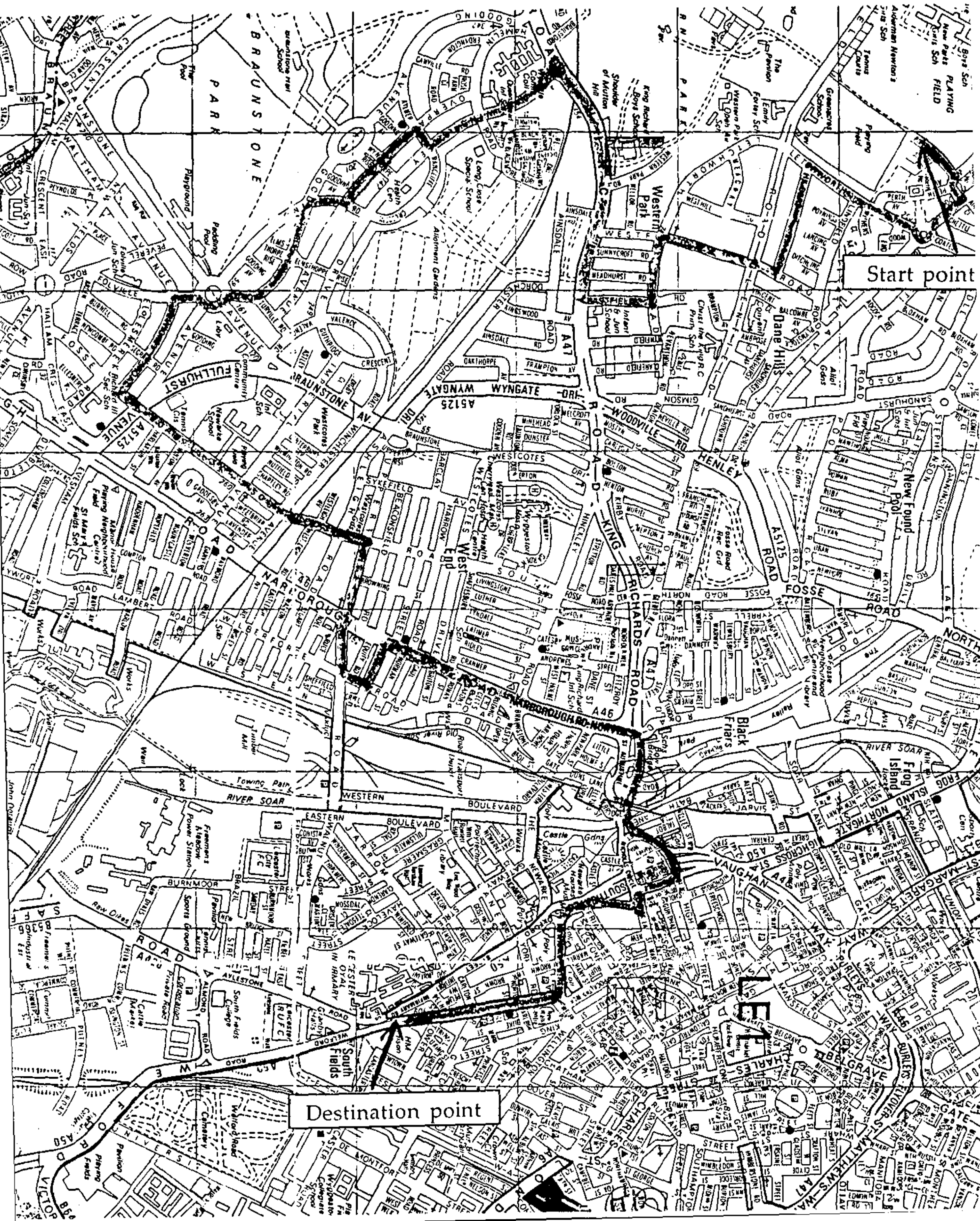
Text instructions when brief for short or simple journeys are for me easier to follow than maps. Instructions with road names/numbers are easier to translate into visual comparison (with surroundings) than distances or just landmarks.

Maps with nothing but lines are useless as they cannot be trusted?

Generally I find text always easier to follow.
Subject 198
SS is easy to look at and put to memory.
IS - also easy to memorise.
SL - basic to remember.
ID - getting more complicated for only one look.
IR - not very clear, could take wrong turning.
SD - too much detail in distance, no landmarks.
IL - no road names e.g. Queens Avenue, etc.
SR - reasonable if own sense of direction is good.
Subject 199
Some directions had inadequate reference points to be able to check whether you were on the right road or not. Distances can be difficult unless at least a couple of miles (to keep checking safely speedometer/mileage 10/10 mile readings) whilst on the move.
I like to get a feel of where I am going and can turn the map/sketch around as I make the turnings.
Subject 200
I thought that map marked 1 (SL) was most clearly marked with obvious landmarks whilst the others were still all reasonably clear and straightforward but some were slightly more vague than others.
I found it difficult to choose one particular choice as they all seemed quite clear.

APPENDIX 5A

Map showing route for direction giving study



APPENDIX 5B

Direction giving study: Detailed results - References to landmarks

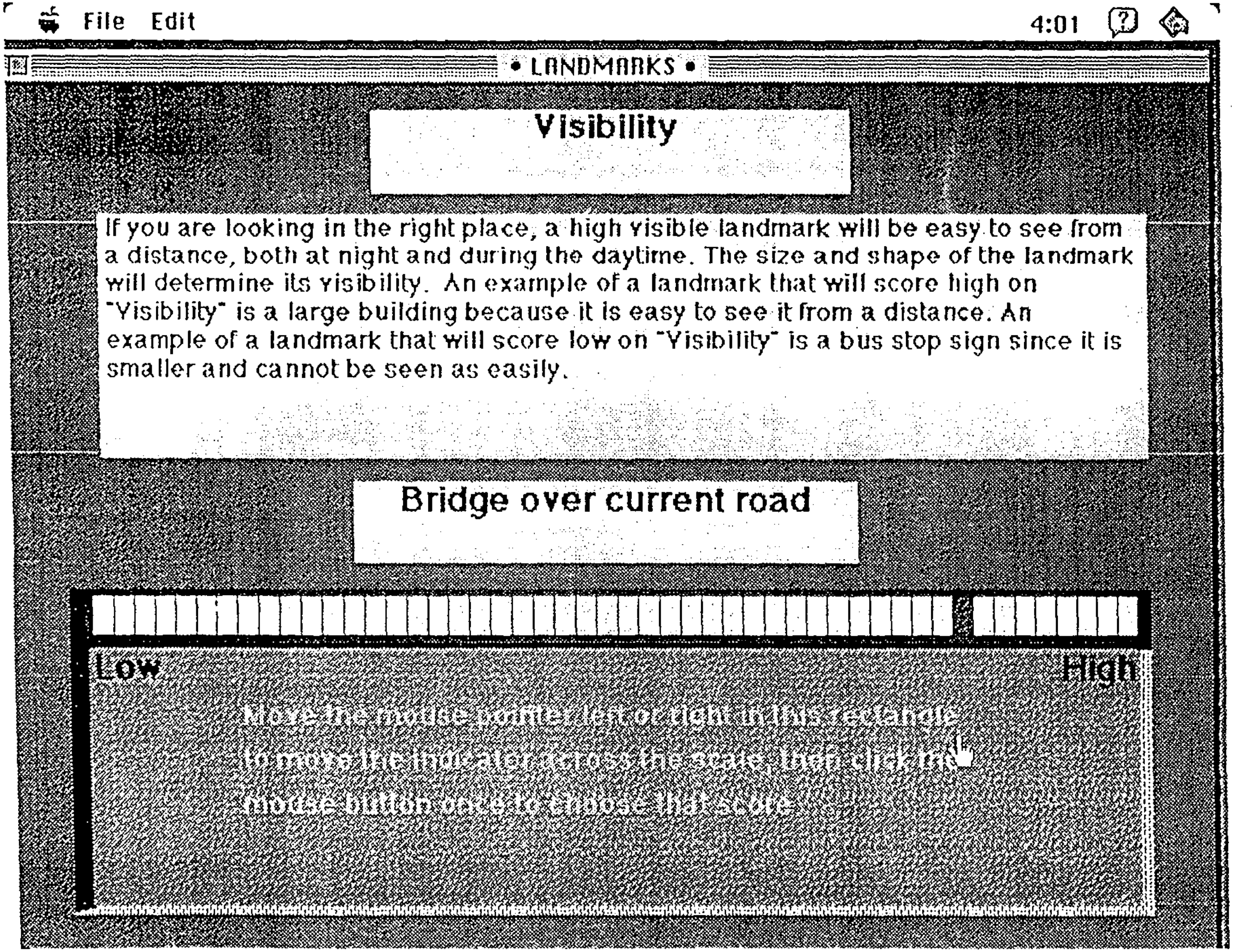
The following table shows the mean, standard deviation and range for the number of references made by subjects to different types of landmark, based on the map or video.

	MAP (n=15)				VIDEO (n=15)			
Landmark type	**Mean**	**SD**	**Max**	**Min**	**Mean**	**SD**	**Max**	**Min**
Traffic Lights	0	0	0	0	9	3.9	14	2
Shops	0	0	0	0	2	1.7	6	0
Bridge	0.5	1.0	3	0	1	0.7	2	0
School	0.4	0.5	1	0	1	0.8	3	0
Post Box	0	0	0	0	0.9	0.8	2	0
Pelican crossing	0	0	0	0	0.7	1.0	3	0
Park/Gardens	0.3	0.8	3	0	0.5	0.6	2	0
Telephone Box	0	0	0	0	0.5	0.5	1	0
Houses	0	0	0	0	0.4	0.8	3	0
Church	0.3	0.6	2	0	0	0	0	0
Car Park	0.2	0.4	1	0	0.1	0.3	1	0
Bus Station	0.1	0.3	1	0	0.3	0.5	1	0
Petrol Station	0	0	0	0	0.3	0.5	1	0
Factory	0	0	0	0	0.3	0.5	1	0
Trees	0	0	0	0	0.3	0.6	2	0
Bus stop/Shelter	0	0	0	0	0.3	0.6	2	0
Flats	0	0	0	0	0.3	0.5	1	0
Theatre	0.1	0.4	1	0	0.1	0.3	1	0
Museum	0.1	0.3	1	0	0.1	0.3	1	0
Poly/University	0.1	0.3	1	0	0.1	0.3	1	0
Monument	0	0	0	0	0.1	0.3	1	0
Wall	0	0	0	0	0.1	0.3	1	0
Railings	0	0	0	0	0.1	0.3	1	0
River	0.1	0.3	1	0	0	0	0	0
Hedge	0	0	0	0	0.1	0.3	1	0
TOTAL	2	3.1	11	0	19	7.5	31	6

Table 5B.1 - Results for references to different landmark types in Map/ Video conditions

APPENDIX 7A

Sample computer screen for landmark ratings



APPENDIX 7B

Landmark rating study
Instructions/definitions given to subjects

Introduction

We would like you to imagine that you are driving a car **on your own** in an **unfamiliar** area. At various points along the route, you will have to decide on actions such as turning left, right or going straight on. To make the correct decisions successfully you will need **information**. This information may come from a variety of sources, for example, maps, written notes, or perhaps the passenger telling you what to do.

These sources may provide a number of different **kinds** of information, for example, information about the type of junction (e.g. roundabout, T-junction), information about the distance to the next turning (e.g. 300m, half a mile) or information regarding **landmarks** (e.g. traffic lights, postbox, shops etc.).

A landmark may be any object in the surroundings. A landmark can be a natural feature such as a river or wood. A landmark can also be a man-made object such as a bridge, church or postbox. A landmark may help you to find the correct turnings, and/or may confirm that you are still on the correct route.

There are a number of factors or characteristics that will be important for a '**good**' landmark to possess. These all relate to what the landmark looks like and where the landmark is usually situated. These different factors are given below. Each factor has a description, and an example to clarify what is meant.

Landmark ratings - Definitions given to subjects

- **Predictability in location** - A landmark with a predictable location will be easy to find, because it will be simple to know where to look for the landmark.

  Example:
  Lampposts have a predictable location, as they are always situated at the side of the road. A barn does not have a predictable location, as it can be found anywhere in relation to the road.

- **Familiarity** - If a landmark is familiar, most people will know what it is.

  Example:
  Everybody is familiar with what a "graveyard" is. It is likely that some people will not know what a "chapel" is.

- **Conspicuity** - A conspicuous landmark will draw your attention towards it, whether or not you are specifically looking at it. This may be due to the landmark having flashing lights, bright colours etc.

  Example:
  A lighthouse is a conspicuous landmark because it catches your attention. An electricity pylon is not conspicuous as you won't notice it unless you are looking at it.

- **Usefulness of location** - A usefully located landmark will usually be positioned in such a place that it can be easily related to a turning, or change in direction.

  Example:
  A landmark in the middle of a field does not have a very useful location, as it may be some distance from the road. A landmark on a street corner has a useful location, as it can easily be used to describe a turning.

- **Openness**- A highly open landmark is unlikely ever to be concealed or obscured by other objects such as parked cars, lorries, or even vegetation.

  Example:
  A tower block is highly open, since it is unlikely to be obscured by other objects. However, a grit box is not so open, since it is likely to be obscured by other objects such as parked vehicles.

- **Permanence** - A permanent landmark is unlikely ever to move from its present location.

  Example:
  A mountain is a permanent landmark as it will never move. A mobile crane is not a permanent landmark as it will often move its position.

- **Compactness** - A compact landmark will be of a size that allows it to relate to a single turning and not a number of turnings.

  Example:
  A landmark such as a small corner shop is compact and can be used to identify one particular turn. A landmark which is very large and spread out, for example a park, may relate to a number of turnings.

- **Predictability in appearance** - If a landmark has a predictable appearance, it will be easy to foresee exactly what the landmark will look like.

  Example:
  Rubbish skips have a predictable appearance, since, if you are looking for one, you will know what it is likely to look like. Hospitals do not have such a predictable appearance. If you are looking for a hospital you will not know exactly what it will look like.

- **Visibility** - If you are looking in the right place, a highly visible landmark will be easy to see from a distance, both at night and during the daytime. The size and shape of the landmark will determine its visibility.

  Example:
  A large building is highly visible because it is easy to see it from a distance. However, a bus stop sign is not so visible, since it is smaller and cannot be seen as easily.

- **Uniqueness** - If a landmark is unique there will be no other different types of landmark which are similar in appearance.

  Example:
  A water tower has a unique appearance. Although there may be many different types of water tower, there are no other objects that look like them. A telegraph post does not have a unique appearance, as other objects such as poles and lampposts also have a similar appearance.

- **Degree of separation** - Landmarks with a high degree of separation will not be situated in close proximity of each other.

  Example:
  Police stations do not usually occur close to each other (are highly separated). Street lamps are not highly separated, as many occur close to one another.

Landmark ratings - Experimental instructions given to subjects

For this experiment we would like you to rate a number of different landmarks (postbox, traffic lights, park etc.) against each of the 11 factors that you have just read. You will be asked to place a mark on a scale from low to high.

We have provided you with a computer to allow you to carry out this task. Please look at the screen and proceed with the following steps:-

1. At the top of the screen is the name of one of the 11 factors. Immediately below this is the factor's definition, including examples of landmarks that would score low or high on this factor. Please read this definition carefully.

2. Below the definition there will be the name of a landmark. Below the name of the landmark there is a yellow continuous scale marked from low to high. Think about how the landmark would score for this factor, based on your previous experience. NB do not spend too long making your decision. We are interested in your initial feelings.

3. **When you are ready, we would then like you to click at the point on the scale which represents what you believe is the magnitude of the factor for that landmark.** The computer will then move onto the next landmark. The factor will remain the same until you have rated all landmarks (there will be 14) for this factor.

4. Now repeat steps 2 to 3.

5. When you have rated all the landmarks for this particular factor you will hear a 'beep'. The factor name and definition will then change. Read this new definition carefully, and then rate all the landmarks for this new factor, i.e. repeat steps 2 to 4.

6. When you have rated all the landmarks for all the factors, the computer will inform you that **you have finished this stage of the experiment.** Please inform the experimenter.

If you have any queries regarding what is expected of you please ask the experimenter.

APPENDIX 7C

Detailed results for all landmarks

Name of landmark	Permanence	Predictability in Location	Conspicuity	Visibility	Openeness	Familiarity	Predictability in Appearance	Degree of separation	Uniqueness	Usefulness of Location	Compactness	Overall Rating
Advertising Hoarding	22 (10-31)	28 (16-39)	35.5 (24-41)	36 (31-44)	38 (29-45)	42 (32-46)	38 (31-42)	20 (8-29)	31 (21-36)	37 (27-41)	39 (30-43)	36 (29-42)
Bend in road	39.5 (23-47)	31 (15-47)	22 (8-39)	29 (18-37)	35 (19-45)	41.5 (28-44)	26.5 (12-34)	16.5 (6-25)	17 (8-26)	33 (19-39)	26 (19-38)	27 (26-38)
Bridge over current road	41 (37-45)	43.5 (23-46)	35.5 (26-46)	41 (33-46)	43.5 (36-47)	41 (35-46)	44 (33-48)	31.5 (24-39)	41 (26-47)	40 (33-45)	39.5 (36-44)	42 (35-47)
Brow of a hill	46 (40-48)	24.5 (9-43)	26 (14-36)	33 (20-40)	40.5 (33-46)	34.5 (28-41)	30 (16-39)	28.5 (19-37)	24 (16-34)	31.5 (20-41)	29.5 (16-41)	26.5 (16-39)
Bus stop	24 (16-34)	40 (30-44)	13 (7-22)	10 (5-19)	10.5 7-18)	42 (38-47)	38 (32-46)	14 (8-29)	16 (9-32)	39 (28-46)	44 (34-47)	25.5 (16-36)
Bus/Coach station	37.5 (31-42)	31 (19-37)	30 (24-40)	34 (27-40)	39.5 (32-42)	37 (31-43)	27 (17-39)	40 (35-44)	28 (20-37)	31 (23-39)	25 (17-39)	34 (28-38)
Church	43 (38-47)	16.5 (12-31)	34.5 (25-40)	39.5 (32-43)	40 (37-44)	44 (38-47)	38.5 (27-45)	36 (32-41)	35.5 (23-40)	36 (29-40)	39 (30-42)	37 (33-44)
Cinema	33.5 (25-38)	23 (16-30)	31 (26-37)	35 (26-39)	32 (27-38)	40 (33-43)	28.5 (14-36)	36.5 (26-43)	29 (17-36)	34 (27-40)	32.5 (24-38)	35 (29-39)
Dip in road	37 (13-42)	33.5 (10-42)	20 (8-27)	13 (6-29)	23 (14-37)	26.5 (17-39)	18 (11-34)	16.5 (6-27)	19 (8-31)	28.5 (14-40)	25.5 (17-38)	23 (12-32)
Factory	31.5 (24-40)	18 (9-27)	29.5 (21-37)	32 (27-39)	37.5 (30-41)	36 (28-42)	26 (12-32)	42 (34-47)	35 (24-42)	35 (25-40)	24.5 (18-35)	35 (23-39)
Hump-backed bridge	41 (36-46)	39 (21-46)	32 (22-42)	35.5 (23-45)	39 (33-46)	36 (28-42)	38.5 (28-46)	38 (25-44)	35.5 (26-42)	40 (33-46)	40.5 (38-44)	41 (33-44)
Monument	44.5 (41-48)	12.5 (7-24)	35.5 (25-47)	36 (21-43)	38.5 (28-45)	30.5 (22-40)	19 (8-33)	40.5 (35-46)	41 (36-47)	33.5 (24-41)	41 (30-45)	39 (31-44)
Multi-storey car park	40 (33-45)	29 (16-37)	29.5 (21-42)	40.5 (31-46)	42 (38-47)	40.5 (30-47)	37 (27-42)	33.5 (25-38)	27.5 (18-35)	35.5 (30-40)	24.5 (16-36)	32.5 (28-37)
Pelican crossing	38.5 (25-44)	46 (40-48)	45 (37-48)	41 (37-46)	41 (27-47)	44 (36-49)	47.5 (42-49)	28 (18-38)	41.5 (21-47)	44 (40-48)	44.5 (40-48)	44 (38-47)
Petrol station	30.5 (26-43)	39 (30-44)	36.5 (30-41)	39 (30-43)	38 (31-44)	45 (39-47)	43 (37-46)	25.5 (19-33)	30.5 (15-41)	39 (33-44)	37 (30-42)	40 (30-42)

Appendix 7C - Median values and inter-quartile ranges (in brackets) for each of the attributes and the overall definitions - all landmarks

Name of landmark	Permenance	Predictability in Location	Conspicuity	Visibility	Openeness	Familiarity	Predictability in Appearance	Degree of separation	Uniqueness	Usefulness of Location	Compactness	Overall Rating
Postbox	37.5 (32-43)	37.5 (23-43)	12.5 (8-31)	12 (5-18)	11 (7-21)	46 (41-48)	45.5 (39-48)	27 (13-36)	28.5 (17-45)	41 (32-45)	47 (40-48)	33 (24-42)
Public House	35.5 (32-38)	29 (18-35)	31 (21-35)	32.5 (24-38)	33 (27-36)	39.5 (36-44)	27 (21-37)	21.5 (13-32)	23.5 (18-38)	37.5 (32-43)	38.5 (34-43)	36.5 (35-40)
Railway line	40.5 (36-43)	12.5 (4-25)	14 (7-22)	17 (10-31)	22.5 (8-30)	41.5 (36-45)	40 (26-48)	26 (11-36)	35 (26-44)	16.5 (10-25)	11 (4-23)	17.5 (12-31)
Railway station	42 (38-44)	27 (12-37)	34.5 (26-41)	37 (32-41)	37.5 (31-45)	42.5 (39-46)	35.5 (27-41)	43 (39-47)	34 (28-41)	37 (31-43)	31.5 (15-39)	38 (32-44)
Repairs garage	21 (13-33)	17 (8-30)	17 (11-28)	21.5 (13-32)	24.5 (16-33)	23 (13-35)	21 (12-30)	24.5 (19-35)	15 (9-20)	24.5 (21-32)	35 (25-39)	26.5 (19-34)
River	47.5 (44-50)	15 (6-28)	24 (13-33)	21 (12-36)	26 (12-39)	45.5 (40-48)	39.5 (31-47)	40.5 (31-45)	35 (24-46)	14.5 (6-30)	12 (6-27)	23 (11-33)
Road sign/ signpost	31.5 (16-40)	43 (36-46)	26.5 (12-38)	20.5 (9-35)	24 (9-35)	43 (39-46)	40 (34-45)	19 (8-34)	22.5 (10-37)	44.5 (35-47)	45.5 (40-48)	36.5 (30-42)
School	41 (36-46)	21 (12-31)	28 (18-36)	34 (25-38)	34 (25-38)	39 (35-43)	26 (18-32)	35 (25-41)	29 (22-37)	37 (23-39)	34 (20-41)	33 (25-39)
Shop/ restaurant	22 (15-31)	24 (14-33)	28.5 (17-35)	25 (16-33)	30.5 (18-34)	35.5 (29-40)	23 (13-30)	38.5 (29-43)	30 (14-38)	35 (29-43)	37 (33-43)	35.5 (25-40)
Street name signs	39 (28-46)	42.5 (31-46)	12.5 (4-25)	11 (5-21)	9 (3-15)	45 (40-48)	38.5 (31-45)	17 (5-38)	25 (14-43)	44 (35-48)	45.5 (37-48)	38.5 (22-46)
Superstore	32.5 (23-38)	23.5 (15-34)	37.5 (30-42)	39 (32-42)	40.5 (30-45)	39.5 (34-44)	31 (25-39)	40 (32-46)	33.5 (23-41)	35.5 (26-41)	28.5 (18-36)	39 (29-44)
Telephone box	32 (25-39)	44 (37-47)	16 (8-26)	18 (9-29)	14.5 (8-31)	46 (41-48)	44 (37-47)	23.5 (12-37)	32.5 (16-43)	38.5 (29-43)	46.5 (40-48)	34 (22-43)
Traffic lights	38 (34-46)	47 (44-48)	43 (31-48)	41.5 (36-49)	44 (33-47)	47.5 (45-50)	49 (46-49)	22 (10-34)	38 (11-48)	46.5 (43-49)	47 (42-49)	47 (40-48)
Wood/Forest	43 (38-47)	13.5 (6-24)	30 (22-40)	34.5 (25-43)	42 (38-46)	42 (35-47)	41 (30-46)	35.5 (24-42)	34.5 (16-44)	18 (8-29)	7.5 (4-18)	23 (11-30)

Appendix 7C - Median values and inter-quartile ranges (in brackets) for each of the attributes and the overall definitions - all landmarks (cont..)

Name of landmark	Perm- enance	Predict- ability in Location	Consp- icuity	Visi- bility	Open- eness	Famil- iarity	Predict- ability in App- earance	Degree of sep- aration	Uniq- ueness	Useful- ness of Location	Comp- actness	Overall Rating
Advertising Hoarding	21.64	27.42	33.44	35.36	36.33	37.83	35.14	21.50	28.47	33.89	35.75	34.75
Bend in road	34.17	30.19	23.56	27.00	32.03	35.58	25.00	18.06	18.97	29.53	27.39	26.25
Bridge over current road	39.75	35.11	33.56	38.72	40.67	38.42	38.31	30.22	35.28	37.78	35.67	38.50
Brow of a hill	41.86	25.81	25.53	29.61	37.78	32.39	28.25	28.03	24.50	29.39	27.50	26.89
Bus stop	24.81	35.39	16.14	13.81	12.97	40.31	36.50	18.86	19.78	34.44	37.69	24.72
Bus/Coach station	35.14	27.75	30.69	32.92	35.92	35.64	27.94	37.94	27.14	30.83	26.92	32.11
Church	41.06	21.17	31.06	36.06	38.11	40.92	34.81	36.11	31.72	33.83	35.44	35.61
Cinema	29.78	23.78	29.75	32.25	32.50	37.78	26.08	32.69	26.22	32.00	30.61	32.97
Dip in road	29.81	27.33	19.36	19.14	24.72	25.00	21.89	17.69	21.36	27.64	26.11	22.33
Factory	29.56	19.39	28.56	32.28	35.25	33.06	24.17	37.97	31.39	31.47	25.64	31.61
Hump-backed bridge	38.08	33.31	31.22	32.81	36.92	34.83	36.42	34.06	33.42	37.89	38.89	38.31
Monument	42.67	17.56	34.00	31.67	34.92	29.06	20.86	38.61	38.36	31.25	36.25	35.94
Multi-storey car park	36.92	26.50	30.61	37.67	40.89	37.17	33.58	31.08	26.17	32.72	26.03	32.53
Pelican crossing	35.56	42.00	38.61	38.06	36.64	40.97	44.44	27.83	33.97	42.08	42.75	41.39
Petrol station	30.39	35.31	34.39	36.42	36.78	42.31	39.89	26.14	27.81	37.67	34.25	35.97
Postbox	34.69	32.97	18.11	14.83	14.00	43.78	42.67	25.42	28.69	37.92	43.25	32.22
Public House	33.47	27.39	29.17	30.81	30.67	38.17	27.17	22.42	26.08	37.22	36.53	35.22
Railway line	38.69	15.36	17.33	19.42	20.61	39.22	35.61	24.25	33.00	19.03	15.64	19.92
Railway station	40.67	25.97	32.14	36.08	37.47	40.53	34.64	40.28	32.67	35.47	28.64	36.56
Repairs garage	23.19	19.69	18.67	22.92	23.64	24.22	21.50	26.44	15.75	25.78	31.28	27.03
River	45.03	17.58	22.67	22.25	25.08	42.78	36.64	36.39	31.69	17.92	16.58	22.33
Road sign/ signpost	28.83	38.53	26.61	22.69	22.81	41.97	37.94	21.81	22.56	40.78	42.39	37.31
School	39.45	22.38	27.52	29.90	31.41	36.24	25.62	31.07	27.62	32.90	29.83	31.38
Shop/ restaurant	23.17	24.11	26.06	25.11	27.42	34.00	22.75	33.83	26.50	34.58	37.06	32.83
Street name signs	34.67	37.83	17.36	14.53	12.22	41.81	37.92	21.33	26.17	39.69	40.56	33.00
Superstore	29.67	24.83	35.75	35.89	37.31	37.72	30.64	37.08	31.03	33.06	27.03	36.86
Telephone box	29.06	30.42	18.89	19.67	19.14	42.58	41.03	23.53	29.75	34.75	42.61	31.22
Traffic lights	36.75	45.19	39.00	38.83	38.31	45.75	46.47	22.92	31.11	45.08	45.03	43.11
Wood/Forest	40.44	16.97	28.94	33.31	41.00	38.83	37.31	31.42	32.19	19.19	12.08	22.03

Appendix 7C - Means for each of the attributes and the overall definitions - all landmarks

Name of landmark	Perm-enance	Predict-ability in Location	Consp-icuity	Visi-bility	Open-eness	Famil-iarity	Predict-ability in App-earance	Degree of sep-aration	Uniq-ueness	Useful-ness of Location	Comp-actness	Overall Rating
Advertising Hoarding	13.58	13.48	10.44	9.63	9.72	11.95	11.99	13.66	12.40	9.97	10.65	9.80
Bend in road	15.35	16.51	15.06	14.23	14.26	11.78	14.08	13.08	13.88	13.48	12.96	13.49
Bridge over current road	7.84	15.49	13.40	9.12	9.59	10.98	11.89	12.06	13.67	10.13	13.28	11.50
Brow of a hill	9.84	17.62	14.25	14.08	10.25	13.25	14.40	11.92	12.16	13.49	14.21	14.44
Bus stop	12.04	13.57	12.62	11.82	7.86	9.23	11.13	13.79	14.58	14.29	13.77	13.20
Bus/Coach station	10.26	12.98	10.98	8.96	10.12	10.02	13.28	10.27	12.49	10.91	13.69	9.21
Church	9.00	12.83	12.46	9.76	9.50	9.42	13.51	8.00	13.41	11.39	11.07	10.22
Cinema	11.33	10.88	10.68	9.73	8.74	8.57	12.64	12.08	13.38	10.25	10.25	9.76
Dip in road	16.21	16.95	12.86	15.00	14.14	14.85	14.22	12.58	15.03	15.79	12.41	13.01
Factory	11.67	11.65	10.24	10.14	9.38	11.64	13.88	12.27	13.27	11.25	12.67	10.82
Hump-backed bridge	10.06	15.30	12.99	13.18	10.52	9.99	10.39	12.80	12.08	10.16	8.60	9.33
Monument	7.31	14.25	12.68	13.79	12.92	14.07	14.60	11.30	11.78	12.64	12.52	10.73
Multi-storey car park	11.77	13.10	11.85	10.23	8.06	10.82	11.33	10.76	11.61	12.36	12.61	8.86
Pelican crossing	11.44	10.23	13.65	11.68	12.41	9.41	6.83	12.44	16.08	7.75	7.08	8.07
Petrol station	9.82	11.81	8.80	9.46	8.99	7.22	9.02	11.83	15.50	8.19	10.77	9.24
Postbox	12.46	13.40	14.44	12.16	10.35	6.68	8.11	13.80	16.79	9.83	6.73	12.89
Public House	9.14	11.33	9.80	10.21	8.11	9.87	13.46	11.11	12.74	7.91	9.58	9.64
Railway line	8.09	12.13	12.71	13.38	13.81	9.22	14.09	14.45	15.00	12.42	14.38	11.85
Railway station	6.80	13.99	11.31	7.95	8.23	8.58	10.36	11.05	11.13	9.57	14.24	10.64
Repairs garage	13.15	12.35	10.73	12.63	12.62	13.48	12.62	11.12	9.06	11.11	12.05	11.08
River	7.45	13.65	13.04	14.38	15.24	8.10	12.96	11.49	15.20	13.29	14.48	14.12
Road sign/ signpost	12.79	10.91	14.32	15.23	15.38	5.76	9.80	15.59	14.85	9.45	8.18	10.06
School	8.33	12.78	10.48	11.71	9.73	11.14	10.29	12.61	12.43	10.68	13.66	9.66
Shop/ restaurant	10.93	11.98	11.63	10.39	10.22	10.45	12.98	13.10	14.23	9.31	8.40	11.73
Street name signs	13.48	12.20	15.01	13.28	12.45	8.94	8.95	17.61	15.39	11.74	12.34	15.86
Superstore	12.19	12.51	9.16	9.47	9.66	9.17	12.76	11.35	12.60	11.38	12.05	9.13
Telephone box	12.25	13.62	12.63	12.66	13.43	8.21	8.32	14.31	15.56	11.81	7.58	13.96
Traffic lights	10.43	5.80	12.22	11.98	11.95	6.07	4.83	14.28	18.34	5.15	5.00	9.29
Wood/Forest	9.96	13.48	14.13	11.51	7.29	10.83	10.68	12.63	13.69	13.61	11.94	14.09

Appendix 7C - Standard deviations for each of the attributes and the overall definitions - all landmarks

APPENDIX 7D

Detailed results - Factor and regression analysis

In the first instance, observation of the correlation matrix (shown in Table 7.4) showed that all of the attributes, apart from permanence, were significantly correlated with at least one other attribute. For this reason, it was decided not to include permanence in the factor analysis.

Based on a principal components analysis using the remaining 10 attributes, and a scree test, three/four factors were suggested by the data. Factor loadings were obtained for both of these options utilising a varimax rotational strategy, and it was felt that a four factor solution was most interpretable - see Table 7D.1 below:

Attribute	Factor 1	Factor 2	Factor 3	Factor 4
Predictability in location	0.03	-0.74	0.38	0.40
Conspicuity	0.92	-0.18	0.08	-0.24
Visibility	0.96	-0.04	0.04	-0.21
Openness	0.97	0.13	-0.06	-0.14
Familiarity	0	-0.13	0.92	-0.03
Predictability of appearance	0.03	-0.18	0.95	0.01
Degree of separation	0.34	0.26	-0.16	-0.82
Uniqueness	0.43	-0.01	0.43	-0.72
Usefulness of location	0.15	-0.95	0.16	0.06
Compactness	-0.10	-0.96	0.05	0.01
% of variance accounted for by each factor	30.4	25.4	21.4	14.9

Table 7D.1 - Factor loadings (varimax rotated solution)

The above table shows that the four factors, taken together, accounted for 92.1% of the total amount of variance. Furthermore, it is clear that certain attributes had high correlations (loadings) for particular factors. Table 7D.2 summarises these 'principal' attributes, and also provides tentative labels to the underlying factors.

Factor 'label'	Principal attributes included
Visibility	Openness, Visibility, Conspicuity
Location	Compactness, Usefulness of location, Predictability of location
Expectation	Predictability in appearance, Familiarity
Uniqueness	Degree of separation, uniqueness

Table 7D.2 - Summary of principal attributes included within the 4 factors

A stepwise multiple regression analysis was then employed to assess the degree to which a combination of the factorised attribute scales could account for variation in the overall ratings. As an input to this analysis, factor scores were calculated for each of the four factors described above for each landmark.

In a preliminary examination of the data utilising scatterplots, it was revealed that three particular landmarks, wood/forest, river, and railway line, could be treated as outliers (that is, observations that appeared to be inconsistent with the rest of the data). These were then removed from the subsequent regression analysis.

Three of the factorised attribute scales accounted for a significant amount of variance in overall scores, $F(3, 22)=55.2$, $p=0$. The specific contribution of each of the factorised scales to the prediction of overall rating can be observed in the following table.

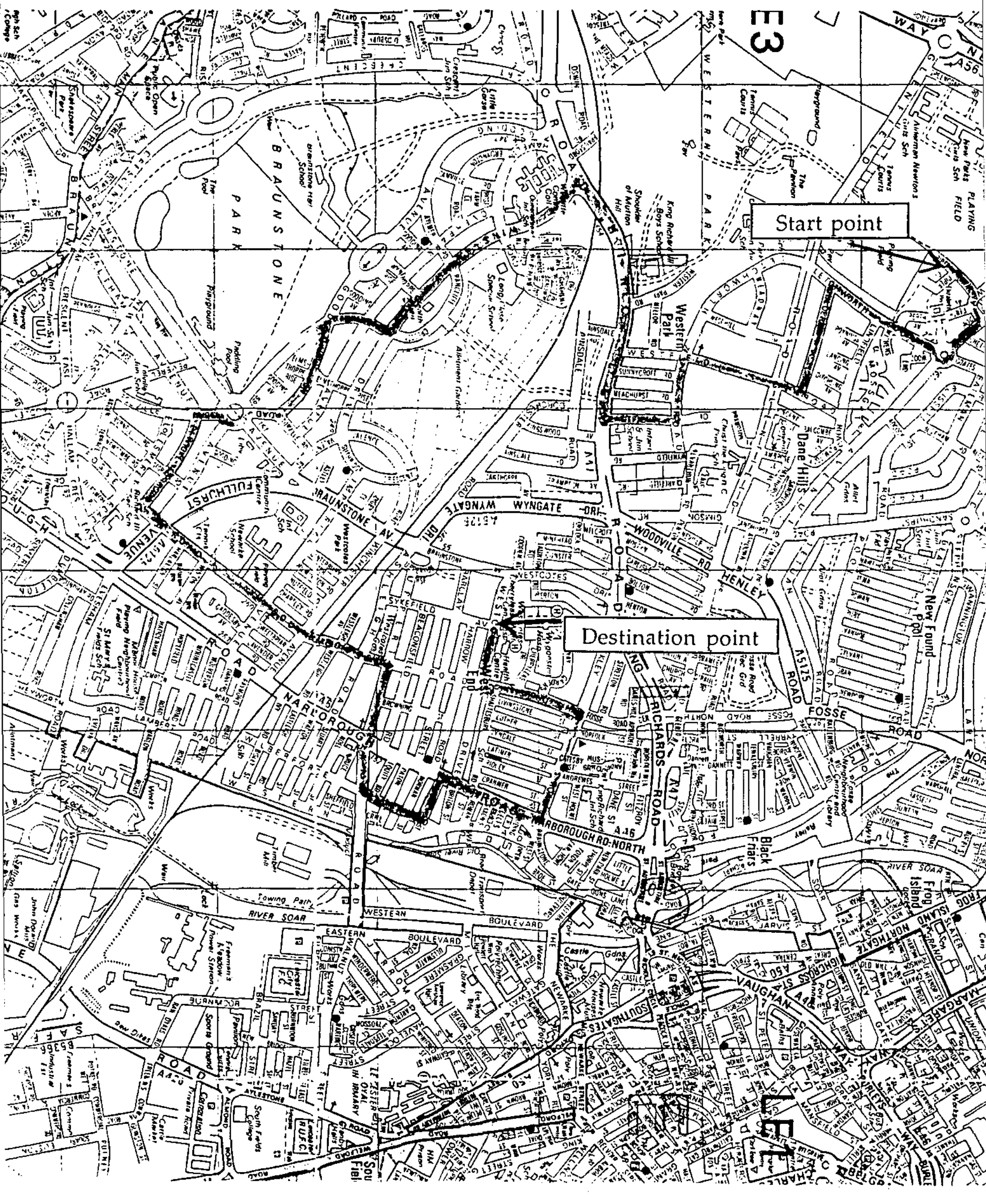
Factor	Coefficient	R^2 added	R^2 -cumulative	Sig level
Location	0.70	0.33	0.33	$p<0.005$
Visibility	0.40	0.44	0.78	$p<0.0001$
Uniqueness	0.22	0.11	0.89	$p<0.0005$
Expectation	/	0	0.89	$p=0.45$

Table 7D.3 - Results of stepwise regression analysis

The table indicates that Location, Visibility and Uniqueness (in that order) are most related to the overall ratings given for landmarks. Furthermore, these three factors account for 89% of the variance in the overall ratings of landmarks.

APPENDIX 8A

Map showing route used in road studies



APPENDIX 8B

Procedure/training used in road studies

Prior to subject arriving:

- Ensure that have correct file for condition

When the subject arrives:

- Check driving licence - it must be clean
- Basic information on the trial and what is going to happen. Format:
  - Run through the car controls
  - Drive to get used to the car
  - Practice drive to get used to what they are going to be asked to do
  - Drive two routes followed by questions about what they have just done
  - Drive back here
  - Total time between 2 and 3 hours
- Questionnaires - I don't care what they say - I want honest opinions.
- I will be taking recordings at certain points - please ignore this.
- Finally, totally confidential - relax and enjoy it - not under test.
- Insured them to take part in the trial. However, that cover does not extend to damage resulting from dangerous driving etc. Although they are taking part in a trial they must obey the law of the land!
- If at any point they do not feel happy please stop - I would rather this happens than someone feeling uncomfortable with what they are being asked to do.
- Briefing on the car:
  - Do they often drive this size of car ?
  - Seat adjustment
  - Mirrors
  - Windows
  - Windscreen wipers and washers, demisters
  - Lights and indicators
  - General run through of heating controls etc.
  - Do not switch off the engine (some of the equipment runs off it).
- While they are adjusted the seat, check the camera views and adjust the light as necessary. Give them the personal details questionnaire to complete.

Practice driving car

- I would now like you to drive the car to get used to the controls and the feel of it. Please ask if there are any problems - I want you to feel happy with the car before proceeding any further.

- Any questions ?

- Write down the time departing Loughborough and weather conditions

Subject drives to First Point

- Once parked up, explain to subject the need for human factors input in the design of these systems

- Then, brief the subject on the task and the symbols (and auditory instructions) and what they will be experiencing - show paper-based examples. Remember to inform subjects that:
  * Information will always be presented 200m before turn
  * Straight on arrow means there is no manoeuvre within next 200 yards
  * Familiarisation route takes about 10 minutes
  * Free to ask questions during this route

- Plug in the LCD display (cigar lighter)

- Turn on the cameras and inverter (Mac supply)

- Check the Mac monitor is off then boot up the Mac

- Select the file - Double check that the correct window is being opened and turn the sound off if appropriate

Subject drives familiarisation route

- Select correct 'Supercard' file and turn off sound, if appropriate

- Encourage them to express verbally any difficulties/opinions as they go along

- Park up. Any problems ?

Brief subject on first condition

- Select correct 'Supercard' file and turn off sound, if appropriate

- Tell the subject to ignore me and to take whatever turns they think are right - I will intervene if they go wrong.

- If you should go wrong I will guide you back on to the correct route (the system does not recalculate routes).

- Turn on the video recorder

Subject drives Experimental Route

- If they go wrong ask why whilst guiding them back onto the correct route

- If they ask before a turn reply, 'Do what you think is right', i.e. tell them to take the route they think is correct.

Subject arrives at end of route

- Ask them to park up - keep engine running !

- "How was that ?" - keep recorders going and make notes

- Turn off the Mac and monitor, the inverter in the boot and the video recorder

- Complete NASA-RTLX (sit in front of car - get them to read background and definitions and then fill in the scales)

- Complete condition questionnaire - stress confidentiality and that they are free to say what they feel

Drive back to HUSAT

- Thank them for their time - if they do know someone else who is doing the trial please don't discuss it with them until they have been through it !

- Pay them and get receipt - give them the white copy and keep the others

After the subject has gone

- Collect together and label all questionnaires and notes etc. relating to the subject

- Cross off subject from list and prepare for the next subject

APPENDIX 8C

NASA-RTLX - Introductory materials, factor definitions and rating scales

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PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

Driving is actually a very complex skill which most of us take for granted. Imagine all the different components and pieces of behaviour which are involved in successfully controlling the vehicle through the traffic environment. For instance, one has to look out for pedestrians, judge distance and speed in relationship to other vehicles, control position on the road via the steering wheel whilst simultaneously attending to gear changes and pedal controls. In other words, driving demands the human to perform a number of tasks at once.

Fortunately an experienced driver learns how to bring together these skills and perform them in a manner which demands little conscious control. This comes with practise and experience on the road. Most of us can remember those days as learner drivers when we were forced to remember each skill in turn and there always seemed to be too much to be done in too little time.

The attached sheet has attempted to break down the driving task into six distinctive components. Please read each through the descriptions of each factor and inform the experimenter when you have finished.

SIX FACTORS WHICH CONTRIBUTE TO THE DIFFICULTY OF THE DRIVING TASK

NB - Navigating is part of the overall task of driving

1. MENTAL DEMAND

This factor refers to any mental demands **placed on you** by the driving task (e.g. in planning, thinking, deciding, remembering, looking, searching). Was the driving task mentally easy or demanding?

2. EFFORT

This factor refers to the mental effort **required by you** to maintain a safe level of driving. Was little concentration required, or did you have to concentrate a lot during the course of the journey?

3. PHYSICAL DEMAND

This factor refers to any **physical activity** you have just experienced whilst driving (e.g. operating the car's controls, using the route guidance device, etc.)

4. TIME PRESSURE

This factor refers to how **hurried or harassed** you felt whilst driving (e.g. due to the presence of other vehicles, traffic flow, following the route guidance information, etc.).

5. DISTRACTION

This factor refers to the extent to which you felt **distracted** from the driving task. Safe driving requires you to demonstrate a reasonable amount of vigilance to events outside the vehicle. Information both inside and outside the car (visual and/or aural) has the potential to distract you from the driving task.

6. STRESS LEVEL

Ideally you should feel relaxed and unworried whilst driving. However, circumstances may cause you to feel stressed (i.e. annoyed, frustrated, worried, irritated). This factor refers to how **relaxed versus stressed** you felt whilst driving.

RATING SCALES

Place a line through each scale that represents the magnitude of each factor on the task written in **bold** below

Driving whilst using the Route Guidance System to Navigate

Mental Demand: Low |——————————| High

Mental Effort: Low |——————————| High

Physical demand: Low |——————————| High

Time Pressure: Low |——————————| High

Distraction: Low |——————————| High

Stress Level: Low |——————————| High

APPENDIX 9A

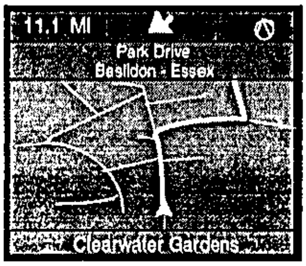
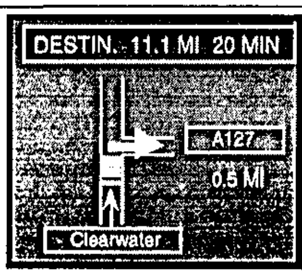
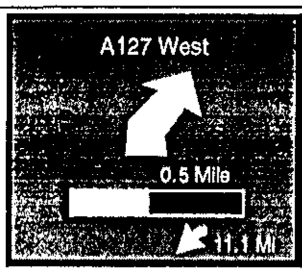
'Pool' of potentially useful navigation information elements - full list

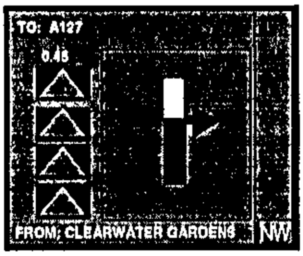
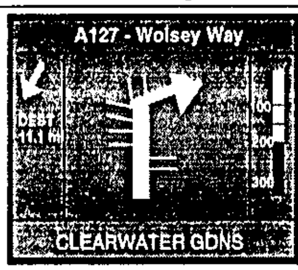
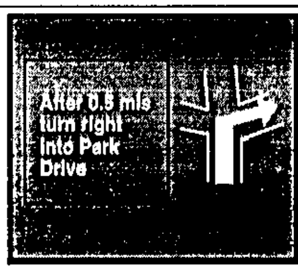
Category	Information elements	Examples
Direction	Ego-centred direction along current road	"Keep going straight on"
	Ego-centred direction of next turning	"Turn left", a "right" arrow
	Ego-centred direction of non-immediate turning	2nd part of a 'stacked' symbol
	Ego-centred direction to destination	An arrow pointing towards the destination
	Ego-centred direction to surrounding roads/junctions/landmarks, etc.	An arrow pointing towards the nearest petrol station
	Local-referenced direction along current road	"Head towards big building"
	Local-referenced direction of next turning	"Turn towards the post-box"
	Local-referenced direction to destination	"Drive towards my house"
	World-referenced current direction	"You are heading South"
	World-referenced direction of next turning	"Turn, heading North"
	World-referenced direction of non-immediate turning	Highlighted route with non-immediate turn on North-up map
	World-referenced direction of destination	"The destination is North-West"
	World-referenced direction to surrounding roads/junctions/landmarks, etc.	Church shown relative to current car icon on North-up map
Distance	Absolute distance to next turning	"turn left in 300m"
	Absolute distance to non-immediate turning	"After the next turn, turn in 50 metres"
	Absolute distance to destination	"The destination is 2 km away"
	Absolute distance to surrounding roads/ junctions/ landmarks, etc.	"The nearest restaurant is 3 miles away"
	Relative distance to next turning - referenced to previous turning	A countdown bar that reduces between previous/next turning
	Relative distance to next turning - referenced to approaching point	A countdown bar that reduces on approach to a turning
	Relative distance to destination - referenced to start point	"You are half way there"
	Relative distance between surrounding roads/junctions/landmarks, etc.	Information on map view
	Cost-based distance to next turning	"Turn right soon", "left now"
	Cost-based distance to non-immediate turning	"After the next turn, turn immediately"
	Cost-based distance to destination	"Your destination is far away"
Path (Road)	The class of the current road	"You are on the A47"
	The class of the next road	"Turn onto the main road"
	The class of non-immediate roads	"You will travel on a motorway on your journey"
	The class of surrounding roads	Colour coding of the class of different off-route roads
	Geometry of the current road	"follow road around bend"
	Geometry of the next road	A bend shown in the next road

Path (Road) cont....	Geometry of non-immediate roads	A hill shown on a later road
	Geometry of surrounding roads	Bends/dips on surrounding rds
	Lanes to take on current road	"move into right hand lane"
	Lanes to take on the next road	"prepare after this turn to move over to the right"
	Road rules on current road	"Follow one-way road"
	Road rules on next road	"Turn into one-way street"
	Road rules on non-immediate roads	"In the city centre it will be one-way"
	Road rules on surrounding roads	No entry icons on map view
	Prior turns on current road before next decision point	"take 2nd left turning"
	Prior turns along next road before turning	.... then take the 3rd on the right"
Node (Junction)	Angle of next junction	"Take sharp left", "bear right"
	Angle of non-immediate junctions	".after the turn make a sharp left"
	Angles of surrounding junctions	Angles of junctions shown within map view
	Type of next junction	"Turn left at T-junction"
	Type of non-immediate junction	Junction types shown on highlighted route to follow
	Types of surrounding junctions	Types shown within map view
Landmarks	Names of landmarks along current road	"Go through the traffic lights"
	Names of landmarks close to next junction	"turn right at post-box"
	Names of landmarks along non-immediate roads	"Later on you will go past the post office"
	Names of surrounding landmarks	"monuments" within map view
	Descriptors for landmarks	"the white house", "BP garage"
	Locators for landmarks	" shop on corner", "church on left"
	Reference prepositions for landmarks	"right before shop", "left at lights"
Road Signs	Current place name	"You are in Loughborough"
	Next place name	"You are heading for Camberley"
	Non-immediate place name	"You will pass through Upminster on your journey"
	Destination place name	"The destination is Woodhouse"
	Surrounding place names	"Derby" shown on map view
	Number of current road	"The current road is A417"
	Number of next road	"Turn onto M1"
	Number of non-immediate turning	"The B625 will be followed at some point on your journey"
	Destination road number	"The destination is on the A47"
	Number of surrounding roads	"A6", "B212" on a map view
	Name of current road/street	"Keep on Park Drive"
	Name of next road/street	"Turn onto Gilbert Road"
	Name of non-immediate road/street	"left then right onto Empress rd"
	Destination road/street name	"The destination is Elms Grove"
	Name of surrounding roads/streets	"Wolsey Way" on map view
	Number of next junction	"Exit at junction 7"
	Number of non-immediate junction	"On the M25, exit at junction 29"
	Number of surrounding junctions	Junction numbers show on map
	Name of next junction	"left at the Beacon junction"
	Name of non-immediate junction	"turn right and then look for the Forest road roundabout"
	Name of surrounding junctions	Hanger lane gyratory shown on map view of London

APPENDIX 9B

Information present within a range of route guidance systems (in conjunction with Table 9.3)

System/ Reference	Sample HMIs - visual and voice	Information elements
5. Bosch TravelPilot™ - Daniels (1994)	 NO VOICE	Ego-centred direction of next turning Ego-centred direction of non-immediate turning Ego-centred direction to destination World-referenced current direction Absolute distance to destination Relative distance between surrounding roads/ junctions Path geometry - current/next/ surrounding roads Turns on current road prior to next decision point Angle of next junction Angle of non-immediate junction Angle of surrounding junctions Destination place name Name of current road/street Destination road/street
6. Travtek ™- Dingus et al., (1997)	 "Turn right onto A127"	Ego-centred direction of next turning Absolute distance to next turning Absolute distance to destination Relative distance to next turning - referenced to approaching point Cost-based distance to destination Angle of next junction Name of current road/street Number of next road
7. Guidestar™ - Whelan (1995)	 "Take the 2nd turn to the right"	Ego-centred direction of next turning Ego-centred direction to destination World-referenced direction of next turning Absolute distance to next turning Absolute distance to destination Relative distance to next turning Turns on current road prior to next decision point Angle of next junction Number of next road

System/ Reference	Sample HMIs - visual and voice	Information elements
8. Motorola Arrow™ - Whelan (1995)	 "Turn right"	Ego-centred direction of next turning World-referenced current direction Absolute distance to next turning Relative distance to next turning Number of next road Name of current road/street
9. Magneti Marelli PathFinder™ - TecMobility web site (1998, July)	 "Right turn in 600 m"	Ego-centred direction of next turning Ego-centred direction to destination Absolute distance to next turning Absolute distance to destination Relative distance to next turning Turns on current road prior to next decision point Angle of next junction Number of next road Name of current road/street Name of next road/street
10. ComRoad Street Machine™ - Anonymous (1997, May/June)	 "After 0.5 miles turn right into Park Drive"	Ego-centred direction of next turning Absolute distance to next turning Angle of next junction Name of next road/street